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REPORT FOR CONSULTATION ON THE METROPOLITAN BOSTON INTRASTATE AIR QUALITY CONTROL REGION

National Air Pollution Control Administration
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REPORT FOR CONSULTATION ON THE METROPOLITAN BOSTON INTRASTATE AIR QUALITY CONTROL REGION

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The basic background information is presented for the consultation with state and local authorities prior to the designation of air quality control regions as stipulated in the Clean Air Act. Boundaries for the regions are proposed and the factors which are the basis for the proposed boundaries are discussed. Reports for consultation consider these factors: geography; population and economic activity; their prospective growth; probable direction of physical growth; the emission inventory and the location of sources; air quality and pollution transport analysis; regional planning; air pollution control; and governmental jurisdictions.

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PREFACE

The Secretary, Department of Health, Education, and Welfare, is directed by the Air Quality Act of 1967 to designate "air quality control regions" to provide a basis for the establishment of air quality standards and the implementation of air quality control programs. In addition to listing the major factors to be considered in the designation of region boundaries, the Act stipulates that the designation of a region shall be preceded by a consultation with appropriate State and local authorities.

The National Air Pollution Control Administration, DHEW, has conducted a study of the Metropolitan Boston urban area, the results of which are presented in this report. The boundaries of the Region*, as proposed in this report, reflect consideration of all available and pertinent data; however, the boundaries remain subject to revision suggested by consultation with State and local authorities. Formal designation will be withheld pending the outcome of that consultation. This report is intended to serve as the starting point for the consultation.

The Administration is appreciative of assistance received either directly during the course of this study or during previous activities in the metropolitan Boston area from the official air pollution agencies in the State of Massachusetts. Useful data was also supplied

*For the purposes of this report, the word region, when capitalized, will refer to the Metropolitan Boston Intrastate Air Quality Control Region. When not capitalized, unless otherwise noted, it will refer to air quality control regions in general.

by the Metropolitan Area Planning Council, the Old Colony Planning Council, the Central Merrimac Valley Regional Planning District, and the Greater Lowell Area Planning Commission.

INTRODUCTION

> "For the purpose of establishing ambient air quality standards pursuant to section 108, and for administrative and other purposes, the Secretary, after consultation with appropriate State and local authorities shall, to the extent feasible, within 18 months after the date of enactment of the Air Quality Act of 1967 designate air quality control regions based on jurisdictional boundaries, urban-industrial concentrations, and other factors including atmospheric areas necessary to provide adequate implementation of air quality standards. The Secretary may from time to time thereafter, as he determines necessary to protect the public health and welfare and after consultation with appropriate State and local authorities, revise the designation of such regions and designate additional air quality control regions. The Secretary shall immediately notify the Governor or Governors of the affected State or States of such designation."
>
> Section 107 (a) (2), Air Quality Act of 1967

THE AIR QUALITY ACT

Air pollution in most of the Nation's urban areas is a regional problem. Consistent with the problem, the solution demands coordinated regional planning and regional effort. Yet, with few exceptions, such coordinated efforts are notable by their absence in the Nation's urban complexes.

Beginning with the Section quoted above, in which the Secretary is required to designate air quality control regions, the Air Quality Act presents an approach to air pollution control involving closely coordinated efforts by Federal, State, and local governments, as shown in Figure 1. After the Secretary has (1) designated regions, (2) published air quality criteria, and (3) published corresponding documents on

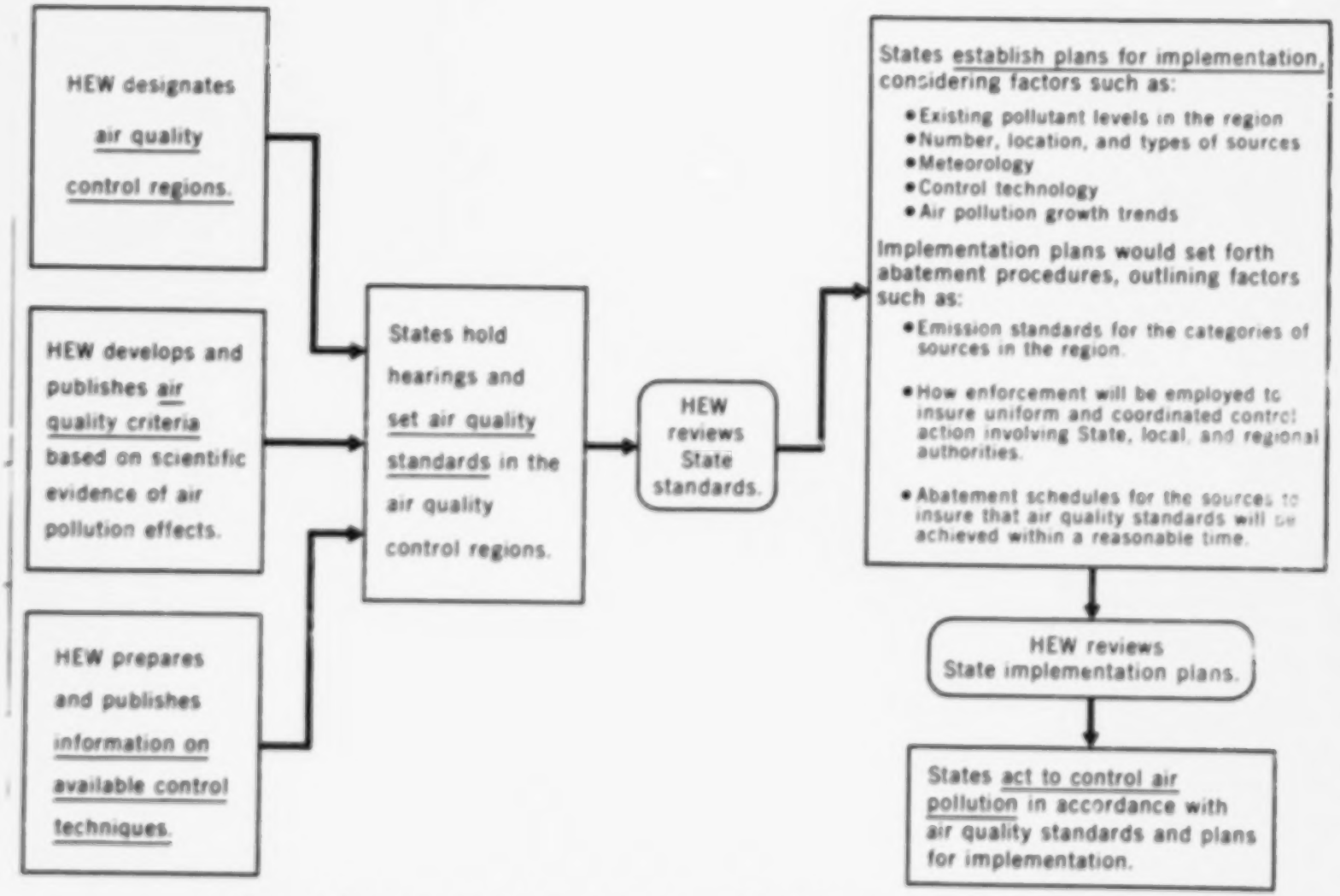
HEW designates air quality control regions.
HEW develops and publishes air quality criteria based on scientific evidence of air pollution effects.
HEW prepares and publishes information on available control techniques.
States hold hearings and set air quality standards in the air quality control regions.
HEW reviews State standards.
States establish plans for implementation, considering factors such as:
• Existing pollutant levels in the region
• Number, location, and types of sources
• Meteorology
• Control technology
• Air pollution growth trends
Implementation plans would set forth abatement procedures, outlining factors such as:
• Emission standards for the categories of sources in the region.
• How enforcement will be employed to insure uniform and coordinated control action involving State, local, and regional authorities.
• Abatement schedules for the sources to insure that air quality standards will be achieved within a reasonable time.
HEW reviews State implementation plans.
States act to control air pollution in accordance with air quality standards and plans for implementation.

Figure 1. Flow diagram for State action to control air pollution on a regional basis.

control technology and associated costs, the Governor(s) of the State(s) must file with the Secretary within 90 days a letter of intent, indicating that the State(s) will adopt within 180 days ambient air quality standards for the pollutants covered by the published criteria and control technology documents and adopt within an additional 180 days plans for the implementation, maintenance, and enforcement of those standards in the designated air quality control regions.

The new Federal legislation provides for a regional attack on air pollution and, at the same time, allows latitude in the form which regional efforts may take. While the Secretary reserves approval authority, the State(s) involved in a designated region assumes the responsibility for developing standards and an implementation plan which includes administrative procedures for abatement and control. Informal cooperative arrangements with proper safeguards may be adequate in some regions, whereas in others, more formal arrangements, such as interstate compacts, may be selected. The objective in each instance will be to provide effective mechanisms for control on a regional basis.

PROCEDURE FOR DESIGNATION OF REGIONS

Figure 2 illustrates the procedures used by the National Air Pollution Control Administration for designating air quality control regions.

A preliminary delineation of the region is developed by bringing together two essentially separate studies - the "Evaluation of Engineering Factors," and the "Evaluation of Urban Factors."

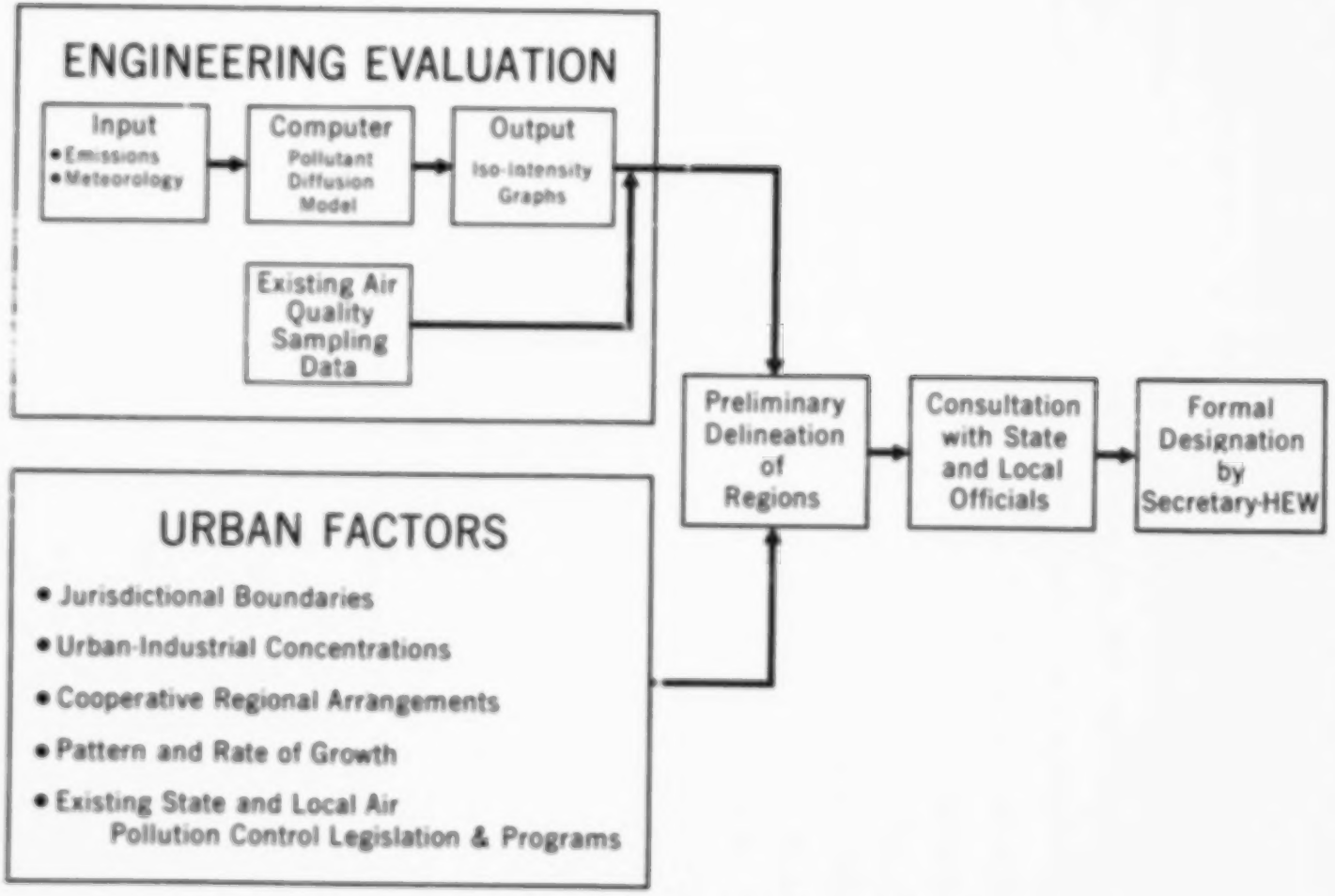

Figure 2. Flow diagram for the designation of air quality control regions.

The "Evaluation of Engineering Factors" considers pollutant source locations and the geographic extent of significant pollutant concentrations in the ambient air. An inventory of air pollutant emissions determines the geographic location and quantities of the various pollutants emitted from the sources in a region. Major quantities of pollution are emitted by automobiles and industry, and from refuse disposal operations, power generation, and space heating.

The subsequent effect of the pollution emitted into the atmosphere is determined by measuring ambient air quality. Since air sampling networks are seldom extensive enough geographically to be used to fix the outer bounds of an air quality control region, a meteorological diffusion model has been developed to predict air quality. Figure 2 indicates that emissions and meteorological input parameters are used by the model to predict spatial dispersion patterns of pollutants. Diffusion model output is presented in terms of equal-concentration contour maps. These graphically describe the predicted pollutant dispersion patterns. In addition, they indicate the geographic extent of pollutant concentration levels in the ambient air. The predicted relative distribution of pollutants is used as a guide to establishing the appropriate size of an air quality control region.

If adequate air quality data is available it may be used to determine the Region. In this study the limited air quality data is used merely as a check on the reliability of the model to predict absolute concentrations. It is also used as an indicator

of the appropriateness of the region determined by comparison with relative concentrations. However, greater emphasis remains on determining the Region by review of the relative pollutant dispersion characteristics.

The "Evaluation of Urban Factors" encompasses all considerations of a non-engineering nature. This evaluation consists of a review of existing governmental jurisdictions, current air pollution control programs, demographic data, current urbanization, and projected patterns of urbanization. The study of urban factors represents an attempt to determine the size of the region that is necessary to include areas where projected urbanization will create increasing air pollution problems.

The findings of the engineering evaluation are combined with the results of the urban factors evaluation, and an initial proposal for the air quality control region is made. As indicated in Figure 2, the proposal is submitted for consultation with State and local officials. After reviewing the official transcript of the consultation proceedings which provides the viewpoints of State and local officials toward the proposal, the Secretary formally designates the region. Formal designation includes a notice in the Federal Register and a notification to the governor(s) of the State(s) affected by the designation.

The body of this report contains a proposal for the boundaries of the Metropolitan Boston Intrastate Air Quality Control Region and the engineering and urban factors evaluations supporting the proposal.

The report itself is intended to serve as a background document for the formal consultation with appropriate State and local authorities.

EVALUATION OF ENGINEERING FACTORS

EMISSION INVENTORY METHODOLOGY AND RESULTS

A quantitative evaluation of air pollutant emissions provides the basic framework for air conservation activities. The compilation of an emissions inventory makes possible the correlation of pollutant emissions with specific geographic locations. This procedure generally results in the identification of the "core" of an air quality control region ----- that is, the area where the bulk of the pollutant emissions occur. In this study, the emissions inventory results are further utilized as input data to a meteorological diffusion model. In this manner the spatial and temporal distribution of the pollution emitted into the atmosphere can be systematically predicted. For these reasons, a presentation of the emissions inventory results serves as a logical starting point in the engineering evaluation.

The emissions inventory for metropolitan Boston was conducted by the National Air Pollution Control Administration. The combined areas of the Boston Standard Metropolitan Statistical Area and the Brockton Standard Metropolitan Statistical Area comprised the region over which the survey was conducted. This 1445 square mile area contains the bulk of the population and urbanization associated with metropolitan Boston. Thus, the inventory conducted over this region includes the preponderance of pollutant emissions in the metropolis. Though pollutant sources in municipalities immediately outside these

SMSA's are not considered, it is felt that the role of these outer areas as receptors of inventoried pollutant emissions will be adequately described, in terms of ambient air quality, by the diffusion model.

The inventory method used, with some modification, for the evaluation of the quantities of the five major pollutants (sulfur oxides*, carbon monoxide, total particulates, hydrocarbons, and oxides of nitrogen) was the Public Health Service rapid survey technique for estimating pollutant emissions.[1] The pollutant emissions were calculated for the year 1967 using Public Health Service emission factors.[2] These factors represent statistical averages of the rate at which pollutants are emitted from the burning or processing of a given quantity of material (e.g., fuel consumption).

Emissions for the survey area were grouped in four general categories. These categories are transportation, refuse disposal, stationary sources, and industrial process emissions. Table I provides a breakdown of SO_2, CO, and total particulate emissions according to these four categories. These four categories are further broken down into subcategories. For transportation emissions, gasoline consumption was calculated using 1966 vehicle-mile data up-dated to 1967.

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*Sulfur dioxide constitutes the overwhelming majority of sulfur oxide emissions. In this evaluation, sulfur oxide emissions are assumed to be composed entirely of sulfur dioxide. Therefore, SO_2 concentrations predicted by the diffusion model, while based on sulfur oxide emissions rather than on SO_2 emissions, will not be significantly overestimated.

TABLE I. SUMMARY OF AIR POLLUTANT EMISSIONS IN THE BOSTON AND BROCKTON SMSA'S, 1967. (TONS/YEAR)

POLLUTANT / SOURCE CATEGORY	SULFUR DIOXIDE		CARBON MONOXIDE		TOTAL PARTICULATES	
	BOSTON	BROCKTON	BOSTON	BROCKTON	BOSTON	BROCKTON
TRANSPORTATION						
GASOLINE VEHICLES	3,200	190	820,000	52,450	4,300	260
DIESEL VEHICLES	400	80	600	150	1,200	200
AIRCRAFT	Neg.	N.A.	10,500	N.A.	1,800	N.A.
RAILROADS	10	N.A.	20	N.A.	30	N.A.
STATIONARY SOURCES						
STEAM, ELECTRIC UTILITIES	137,800	540	6,500	Neg.	23,700	10
RESIDENTIAL	37,600	1,600	4,700	550	12,200	550
COMMERCIAL	187,200		1,100		11,500	
INDUSTRIAL	54,800	(2,160)*	400	(15)*	3,200	(140)*
REFUSE DISPOSAL						
INCINERATION	300	N.A.	400	N.A.	7,200	N.A.
OPEN BURNING	0	N.A.	11,200	840	3,200	4,500
OPEN DUMP	0	N.A.	55,400	N.A.	10,400	N.A.
BARGE BURNING	0	0	10,200	0	2,000	0
INDUSTRIAL PROCESS EMISSIONS	2,200	Neg.	Neg.	840	1,600	60
TOTALS	423,500	4,570	921,000	58,500	82,300	2,060

Neg.: Negligible
N.A.: Not Available
*Combined value for commercial and industrial sources.

Diesel fuel usage was assumed to be 3% of total motor fuel use, as calculated from total vehicle miles traveled. Aircraft emissions data for Logan International Airport (assumed as a point source) was computed using air traffic data (type of aircraft and number of operations) obtained from the Federal Aviation Agency. Railroad fuel consumption was ignored when distributing emissions over the grid system since it amounted to less than 0.5% of total fuel consumed.

Solid-waste generation was based on a national average of 4.5 pounds per capita per day. Estimates of the location and method of disposal by city or town were made, which in turn led to estimates of emissions caused by open dump burning, incineration, backyard burning, and barge burning. Barge burning emissions were not apportioned within the survey area, however, since the burning occurred in the extreme outer harbor.

Stationary source emissions include emissions from both point and area sources. Point sources include power plants and major institutions and industries. Together they account for roughly 50% of the estimated total industrial fuel oil consumption in the survey area. To facilitate the calculation of area source emissions, fuel oil consumption was calculated by pro-rating 1966 Bureau of Mines figures to 1967. The majority of distillate heating oil was assumed to be residential fuel, while most residual oil was assumed to be commercial and institutional fuel. Natural gas usage was apportioned to the cities and towns on the basis of the ratio of gas meters in each city or town to the total number of meters serviced by each gas company. Approximately 65% of the coal consumed in the study

area in 1967 was burned by power plants.

Process emissions were calculated based on available information collected by the Massachusetts Department of Public Health. The industries for which process emissions were calculated were chosen by categories where emission factor data were available.

For the purposes of this report, only sulfur dioxide, carbon monoxide, and total particulate emissions are considered. These three pollutants best represent the spectrum of air pollution sources. Sulfur dioxide emissions best characterize fuel burning activities, especially at point sources. Together, power plants and commercial sources produce, roughly, 77% of the total sulfur dioxide emissions. Carbon monoxide emissions provide the best indication of the impact of the motor vehicle in an area. Eighty-nine percent of the total CO emitted in the survey areas during 1967 was attributed to gasoline consumption, primarily that emanating from automobile exhausts. Total particulate emissions provide an index of the noncombustible components of fuels. All pollution source types contribute significantly to total particulate emissions, with the largest single source category, power plants, producing 28% of the total emissions.

Geographic locations over the survey area are defined by the use of a grid system based on the Massachusetts State Plane Co-ordinate System. The numbered grid system is shown in Figure 3, superimposed over a map of the study area. Grid squares 20,000 feet on a side are located in the highly urbanized portions of the SMSA,

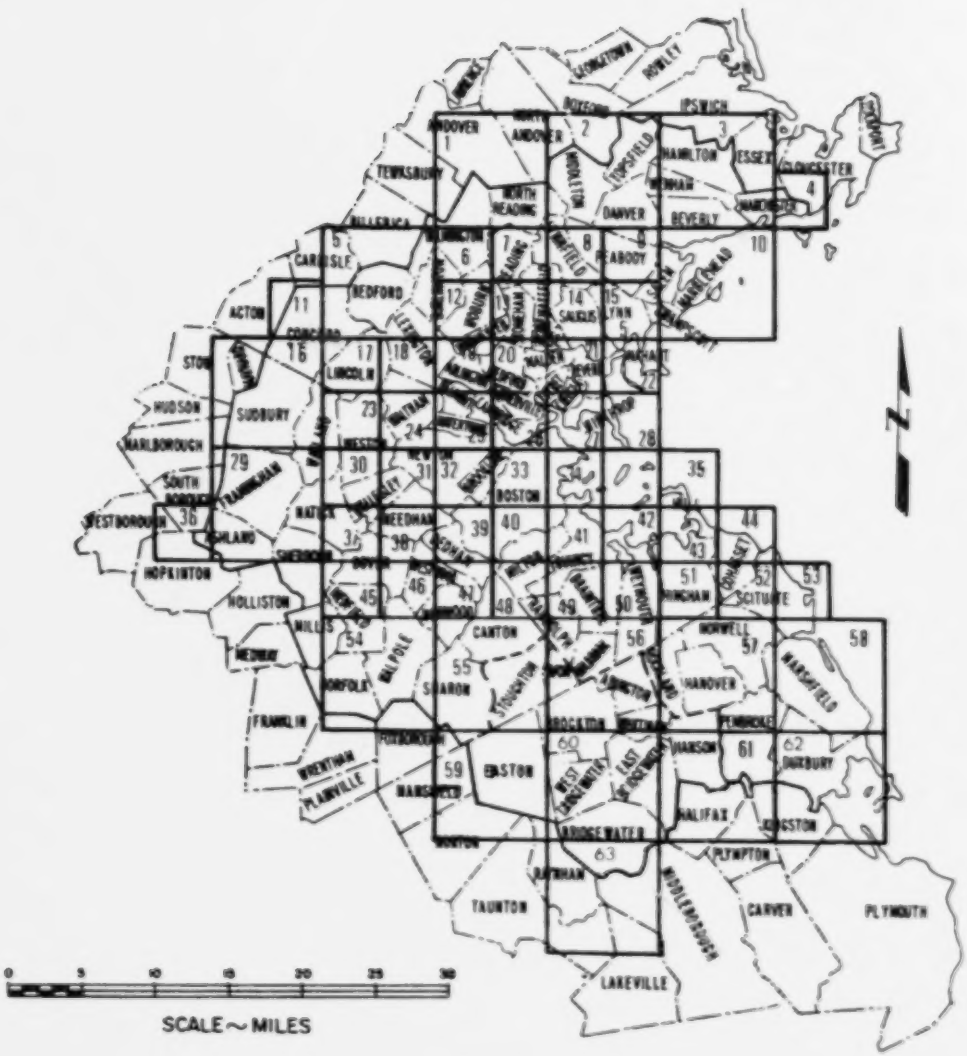

FIGURE 3. EMISSIONS INVENTORY NUMBERED GRID SYSTEM.

while grid squares 40,000 feet on a side are employed in the less densely developed areas. The total of 63 grid squares form the bounds within which pollutant emissions are geographically distributed.

Figures 4, 5, and 6 represent emission density maps for SO_2, CO, and total particulates respectively, based on the grid system. These density maps are constructed according to the yearly average daily emissions for each pollutant, and consider area source emissions only. Table II lists quantities of pollution emitted (tons/day) by time period* and by grid zone for the various pollutants. This table considers area sources only and is the basis for the emission density maps. Table III lists the quantities of pollution emitted from point sources. It lists the type of source (power plant, etc.), as well as the grid zone in which it is located and the emissions for each averaging time. Figure 7 shows the location of major point sources. Taken together, Figures 4 through 7 clearly indicate that the bulk of pollutant emissions occurs in Boston or the immediate vicinity. The magnitude of emissions decreases toward the periphery of the survey area. The correlation between magnitude of emissions and degree of urbanization for the Boston area can be observed by studying the population and residential density maps in the urban factors evaluation. The diffusion model results presented in the next section will help to define the bounds of the Region on the basis of the effects of the inventoried pollutant emissions.

*The various averaging times are broken down as follows: the winter season includes the months of December, January, and February while the summer season includes the months of June, July, and August. The annual averaging period includes all 12 months of the year.

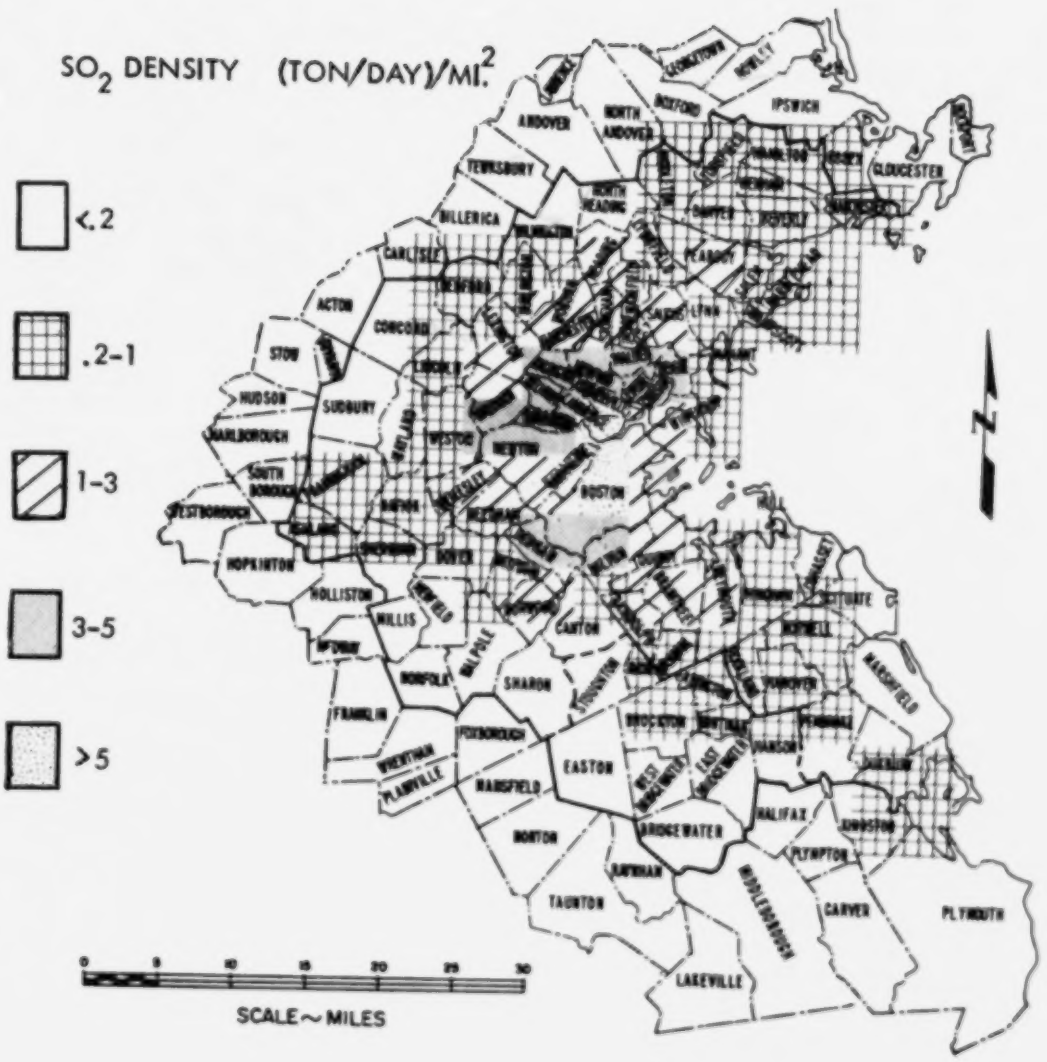

FIGURE 4. SULFUR DIOXIDE EMISSION DENSITIES.

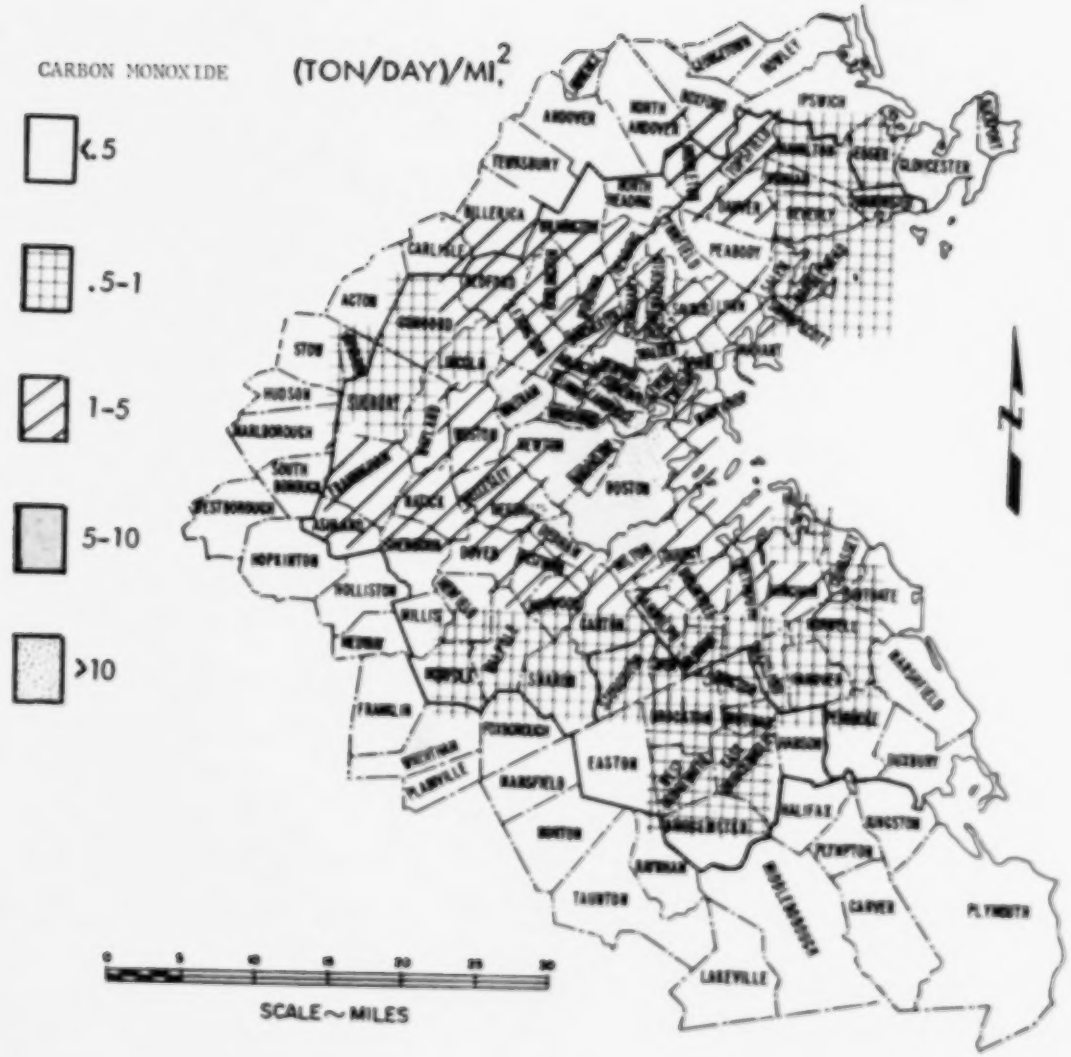

FIGURE 5. CARBON MONOXIDE EMISSION DENSITIES.

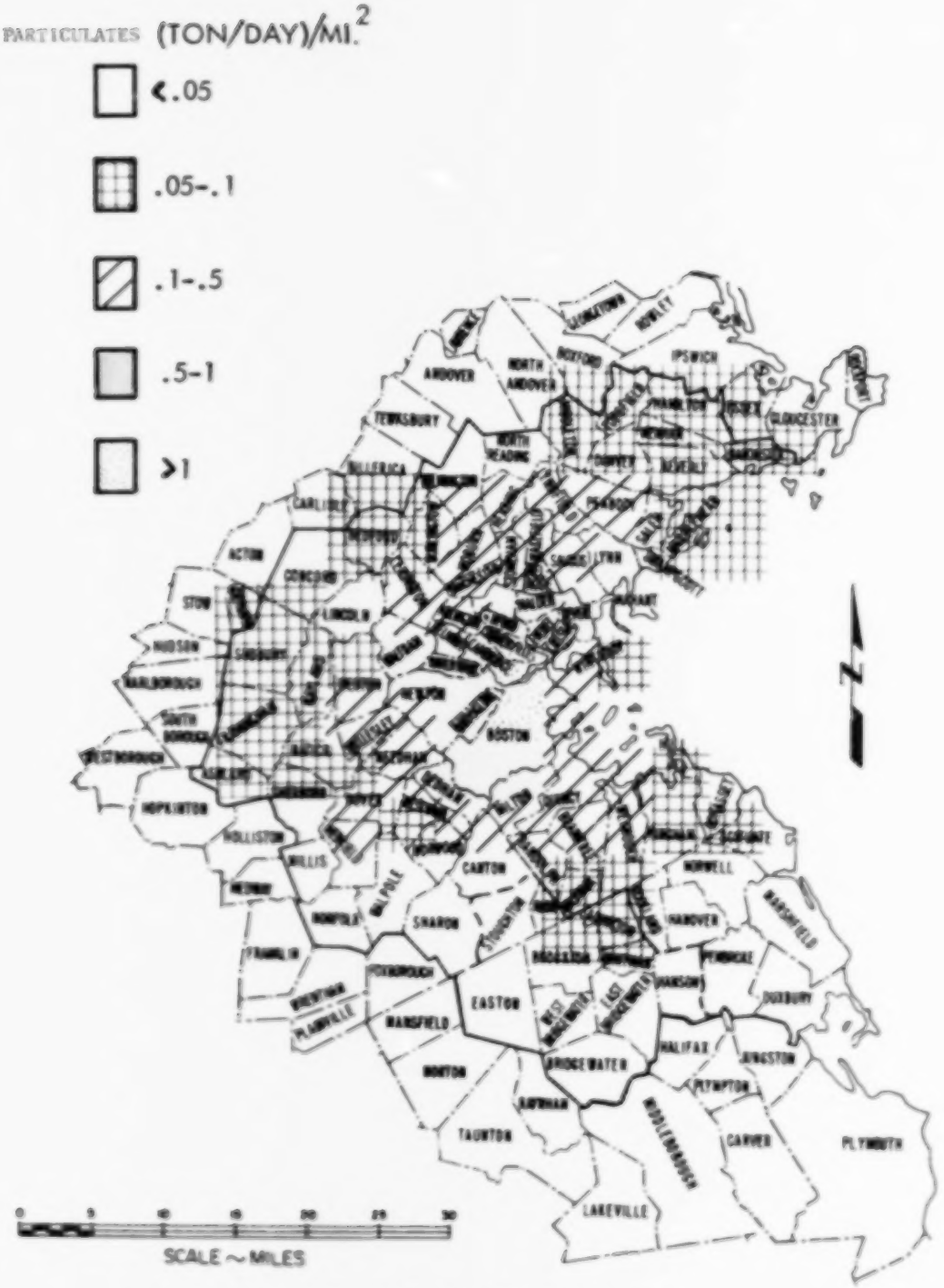

FIGURE 6. TOTAL PARTICULATE EMISSION DENSITIES.

TABLE II. POLLUTANT GRID ZONE EMISSIONS FOR AVERAGE ANNUAL, SUMMER, AND WINTER DAYS (TONS/DAY).

GRID ZONE	ZONE AREA ($mi.^2$)	SULFUR DIOXIDE			CARBON MONOXIDE			PARTICULATES		
		Annual	Summer	Winter	Annual	Summer	Winter	Annual	Summer	Winter
1	57.4	4.46	1.52	7.29	21.39	21.34	21.45	.77	.50	1.08
2	57.4	9.89	3.04	16.34	57.75	57.64	57.88	1.87	1.25	2.60
3	57.4	10.36	3.00	17.23	31.97	31.86	32.11	1.79	1.13	2.56
4	14.4	0.38	0.11	0.61	2.44	2.44	2.45	.07	.05	.10
5	57.4	16.14	11.47	22.60	58.02	57.89	57.17	2.02	1.34	2.83
6	14.4	5.79	1.80	9.58	36.37	36.30	36.45	1.08	.72	1.50
7	14.4	8.87	2.61	14.75	34.22	34.15	34.35	1.47	.92	2.11
8	14.4	6.40	1.80	10.69	2.60	2.52	2.70	1.06	.65	1.56
9	14.4	10.37	3.38	17.05	4.30	2.97	4.42	1.02	1.57	2.37
10	57.4	16.06	4.55	26.93	35.45	35.26	35.65	2.60	1.59	3.79
11	14.4	1.35	0.42	2.22	9.85	9.84	9.87	.26	.18	.36
12	14.4	9.92	2.97	16.46	48.02	47.91	48.16	.98	1.59	2.32
13	14.4	12.46	3.66	20.70	47.55	47.42	47.69	2.07	1.30	2.99
14	14.4	13.58	3.62	22.80	50.82	51.56	51.38	2.44	1.39	3.68
15	14.4	28.57	8.01	47.99	54.98	53.79	56.40	4.98	2.67	7.72
16	57.4	0.75	0.59	1.03	33.94	33.91	33.99	2.63	2.59	2.75
17	14.4	2.08	0.64	3.44	14.08	14.04	14.13	.41	.28	.57
18	14.4	9.04	2.69	14.92	52.63	52.38	52.91	1.64	1.01	2.38
19	14.4	26.20	7.52	43.69	68.18	67.69	68.77	4.18	2.42	6.26
20	14.4	33.33	9.01	55.88	86.30	84.54	88.38	6.08	3.20	9.48
21	14.4	26.50	7.51	44.41	89.80	89.06	90.57	5.05	3.14	7.33
22	14.4	2.11	0.56	3.52	5.65	5.65	5.86	.36	.18	.56
23	14.4	2.57	0.85	4.19	30.61	31.18	31.87	.58	.42	.76
24	14.4	28.70	8.11	47.90	95.41	94.55	96.43	5.05	2.92	7.55
25	14.4	32.10	8.75	53.87	96.86	95.29	98.72	6.61	2.47	8.42
26	14.4	62.17	16.38	104.68	151.70	147.57	156.72	10.60	4.73	17.59
27	14.4	20.78	5.62	34.85	62.04	60.90	63.39	3.15	1.33	5.30
28	14.4	3.13	0.86	5.23	4.85	4.81	4.88	.51	.31	.75
29	57.4	20.63	6.13	34.23	93.70	93.47	93.98	3.76	2.46	5.30
30	14.4	6.10	1.89	10.08	45.08	45.02	45.16	1.14	.76	1.58
31	14.4	14.99	4.37	25.02	65.76	65.46	66.13	2.61	1.60	3.83
32	14.4	22.79	6.23	38.17	93.44	91.97	95.18	4.62	2.17	7.50
33	14.4	58.86	15.65	98.83	164.97	160.95	169.72	7.71	2.13	14.30
34	14.4	15.45	4.10	25.93	43.64	42.59	44.87	2.01	.55	3.74

TABLE II. (CONTINUED)

GRID ZONE	ZONE AREA ($mi.^2$)	SULFUR DIOXIDE			CARBON MONOXIDE			PARTICULATES		
		Annual	Summer	Winter	Annual	Summer	Winter	Annual	Summer	Winter
35	14.4	0.99	0.27	1.66	2.42	2.42	2.44	.15	.09	.23
36	14.4	0.25	0.05	0.42	0.09	0.09	0.09	.03	.02	.05
37	14.4	4.69	1.38	7.83	23.91	23.86	23.97	.83	.53	1.17
38	14.4	6.65	1.97	11.03	24.74	24.66	24.82	1.23	.81	1.72
39	14.4	33.98	9.23	56.93	119.41	117.35	121.84	4.61	1.53	8.25
40	14.4	30.13	8.14	50.52	112.60	96.45	131.64	4.01	1.25	7.27
41	14.4	17.31	4.60	29.08	62.56	61.57	63.57	2.85	1.49	4.67
42	14.4	5.43	1.52	9.08	20.05	19.85	20.27	.91	.50	1.40
43	14.4	2.83	0.81	4.93	11.79	11.77	11.83	1.09	.91	1.30
44	14.4	1.03	0.28	1.74	4.22	4.22	4.25	.17	.11	.25
45	14.4	1.33	0.38	2.22	4.91	4.90	4.92	.22	.14	.32
46	14.4	4.13	1.22	6.87	17.81	17.31	18.41	.73	.47	1.03
47	14.4	7.54	2.22	12.52	32.97	36.80	37.06	1.34	.85	1.91
48	14.4	8.39	2.44	13.98	40.87	40.66	41.12	1.50	.90	2.20
49	14.4	10.72	3.22	17.76	65.78	65.54	66.06	1.94	1.21	2.80
50	14.4	9.23	2.75	15.31	43.05	42.95	43.17	1.70	1.15	2.37
51	14.4	2.96	0.89	4.90	20.55	20.53	20.59	.56	.38	.78
52	14.4	2.63	0.77	4.38	10.81	10.78	10.84	.46	.29	.65
53	14.4	1.35	0.38	2.25	4.62	4.60	4.63	.22	.14	.33
54	57.4	6.67	1.99	11.05	31.40	31.33	31.49	1.24	.83	1.73
55	57.4	7.00	*1.81	*10.12	63.10	*36.21	*36.35	2.12	*.96	*1.75
56	57.4	19.11	*3.93	*22.29	112.25	*50.56	*50.89	4.88	*1.49	*3.31
57	57.4	7.31	*2.21	*12.03	45.24	*43.41	*43.58	1.41	*.90	*1.89
58	57.4	3.36	*1.00	5.59	17.86	17.83	5.69	.63	.41	*.89
59	57.4	.43	*0.06	*0.06	13.81	*0.74	*0.74	.48	*.10	*.10
60	57.4	5.03	N.A.	N.A.	42.17	N.A.	N.A.	1.44	N.A.	N.A.
61	57.4	1.35	*0.30	*1.69	15.29	*7.19	*7.22	.41	*.12	*.26
62	57.4	1.41	0.44	2.30	14.58	14.57	14.59	.28	.20	.39
63	57.4	.17	N.A.	N.A.	6.77	N.A.	N.A.	.18	N.A.	N.A.

*Does not include emissions from Brockton SMSA.
N.A.: Not available.

TABLE III. MAJOR POINT SOURCE EMISSIONS BY GRID ZONE FOR AVERAGE ANNUAL, SUMMER AND WINTER DAYS (TONS/ DAY).

GRID ZONE	TYPE OF SOURCE	SULFUR DIOXIDE			CARBON MONOXIDE			PARTICULATES		
		Annual	Summer	Winter	Annual	Summer	Winter	Annual	Summer	Winter
20	Chemical	1.23	0.22	2.45	.03	.01	.07	.06	0.01	.13
26	Power Plant	1.12	.20	2.21	.0	.0	.0	.05	.00	.09
26	Industry	.59	.10	1.16	.0	.0	.0	.02	.00	.50
25	Institution	.90	.16	1.77	.0	.0	.0	.04	.0	.07
26	Chemical	.72	.13	1.41	.0	.0	.0	.03	.0	.58
12	Industry	2.69	.47	5.30	.01	.0	.02	.11	.19	.22
13	Institution	5.46	.96	10.75	.02	.0	.05	.23	.04	.45
25	Institution	3.37	.59	6.62	.01	.0	.02	.14	.02	.27
26	Industry	2.00	.35	3.94	.0	.0	.0	.09	.0	.18
20	Industry	0.70	.13	1.43	.0	.0	.0	.03	.0	.06
27	Industry	1.21	.21	2.38	.0	.0	.01	.07	.01	.13
47	Industry	0.70	.12	1.34	.0	.0	.0	.02	.0	.07
25	Chemical	1.14	.20	2.24	.0	.0	.0	.05	.0	.09
21	Industry	.70	.12	1.39	.0	.0	,0	.02	.0	.06
20	Industry	.57	.10	1.12	.0	.0	.0	.02	.0	.05
20	Industry	.92	.18	1.96	.0	.0	.0	.06	.01	.11
31	Industry	.71	.12	1.39	.03	.0	.06	.03	.0	.06
9	Industry	3.10	.55	6.04	.02	.0	.03	.12	.02	.25
9	Industry	.70	.12	1.37	.0	.0	.0	.03	.0	.06
9	Industry	2.72	.48	5.35	.01	.0	.02	.12	.02	.24
26	Industry	1.35	.23	2.60	.0	.0	.01	.06	.01	.12
40	Industry	2.84	.80	5.21	.01	.0	.02	.12	.03	.22
32	Industry	.64	.18	1.17	.0	.0	.0	.03	.0	.05
33	Industry	4.67	.76	4.89	.01	.0	.02	.11	.03	.20
3	Industry	.78	.22	1.43	.0	.0	.0	.04	.01	.08
13	Industry	.80	.16	1.76	.0	.0	.0	.04	.01	.08
41	Industry	2.80	.50	5.60	.02	.0	.03	.15	.02	.24
25	Industry	2.70	.48	5.30	.02	.0	.03	.10	.02	.22
20	Institution	.57	.16	1.04	.0	.0	.0	.02	.0	.04
32	Institution	.95	.16	1.80	.0	.0	.02	.04	.0	.08
31	Industry	.52	.15	.95	.0	.0	.0	.03	.0	.05
26	Commercial	.95	.17	1.90	.0	.0	.0	.04	.0	.08
24	Institution	1.88	.53	3.44	.0	.0	.02	.08	.02	.15
19	Industry	.91	.26	1.67	.0	.0	.0	.04	.01	.07

TABLE III. (CONTINUED).

GRID ZONE	TYPE OF SOURCE	SULFUR DIOXIDE			CARBON MONOXIDE			PARTICULATES		
		Annual	Summer	Winter	Annual	Summer	Winter	Annual	Summer	Winter
25	Institution	.80	.22	1.47	.0	.0	.0	.03	.0	.06
10	Institution	.85	.24	1.56	.0	.0	.0	.05	.01	.08
49	Industry	.98	.17	1.91	.0	..0	.0	.03	.00	.08
26	Industry	4.60	1.30	8.43	.02	.0	.04	.20	.06	.36
27	Fed.Facility	1.12	.32	2.06	.0	.0	.0	.05	.01	.08
46	Industry	.81	.23	1.49	.0	.0	.0	.03	.0	.06
25	Industry	1.11	.31	2.03	.0	.0	.0	.05	.01	.08
25	Industry	6.52	1.85	11.95	.03	.0	.05	.27	.08	.49
40	Industry	.0	.0	.0	44.22	44.22	44.22	13.58	13.58	13.58
34	Power Plant	33.86	33.86	33.86	.01	.01	.01	1.72	1.72	1.72
42	Power Plant	93.80	93.80	93.80	.0	.0	.0	2.30	2.30	2.30
26	Power Plant	113.41	113.41	113.41	.01	.01	.01	2.78	2.78	2.78
10	Power Plant	91.72	91.72	91.72	.45	.45	.45	33.35	33.35	33.35
15	Power Plant	8.30	8.30	8.30	.0	.0	.0	.22	.22	.22
26	Power Plant	4.90	4.90	4.90	.0	.0	.0	.14	.14	.14
26	Power Plant	10.97	10.97	10.97	.0	.0	.0	.30	.30	.30
50	Power Plant	3.84	3.84	3.84	.0	.0	.0	.10	.10	.10
42	Power Plant	4.40	4.40	4.40	.0	.0	.0	.10	.10	.10
22	Power Plant	13.33	13.33	13.33	.0	.0	.0	.33	.33	.33

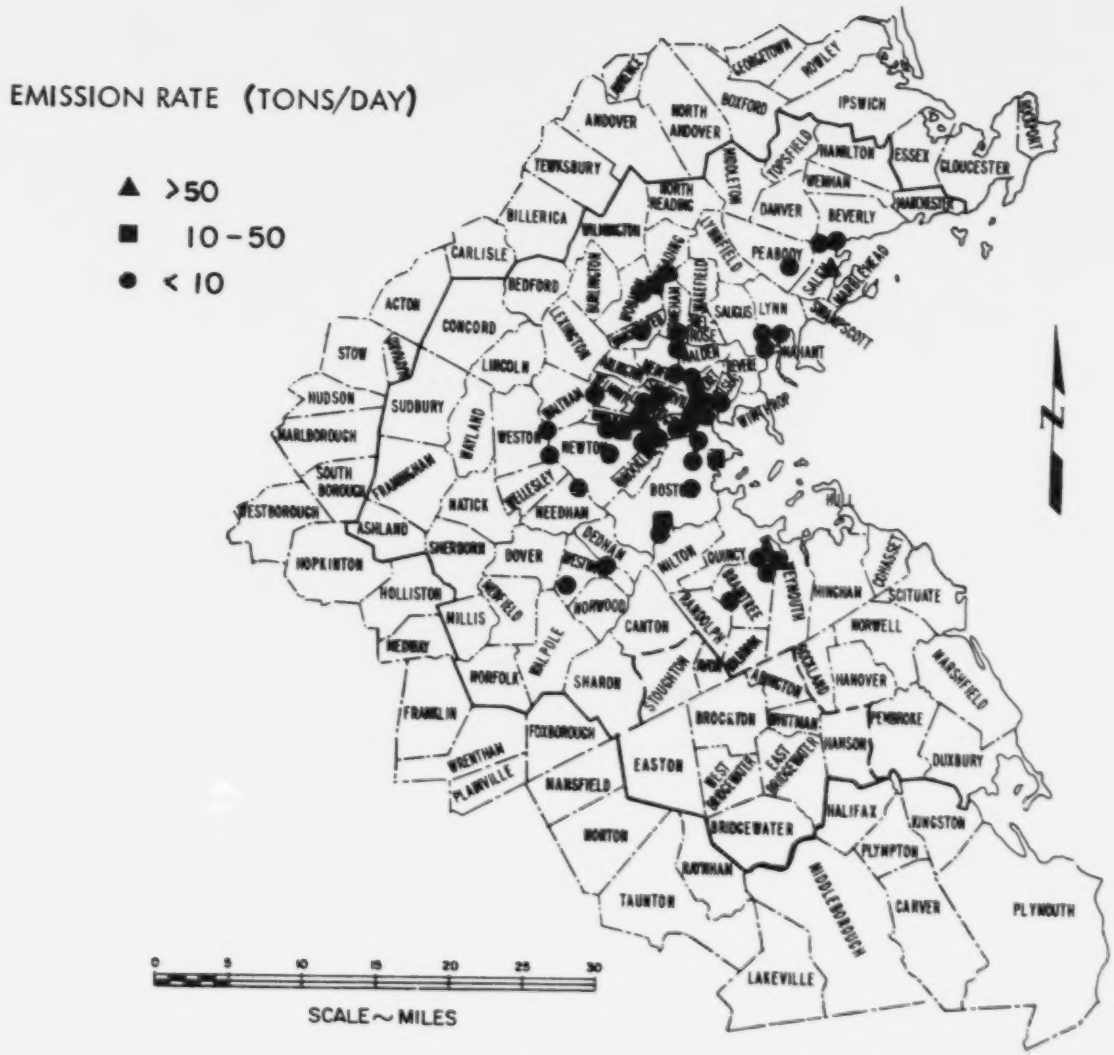

FIGURE 7. LOCATION OF MAJOR POINT SOURCES.

DIFFUSION MODEL METHODOLOGY AND RESULTS

The first major condition established prior to the determination of an air quality control region's boundaries is that the regional boundaries should encompass most pollution sources as well as most people and property adversely affected by the source emissions. The core area of a region can be roughly defined on the basis of point source locations and relative emission densities of "area" sources. The above mentioned condition is not fully satisfied, however, until the bounds of the area significantly affected by the source emissions are determined. Unfortunately, the areal extent of the region, chosen to comply with this condition, cannot be rationally extrapolated from the emissions data alone.

A thorough review of existing air quality in the Boston area would make it possible to define the outer bounds of the region and fully satisfy the source-receptor boundary condition specified above. In Boston, however, existing air sampling networks do not encompass a large enough area, nor have they been in operation over a sufficient length of time, that they may be considered reliable and irrefutable guides to the establishing of the limits of the Region.

In light of this lack of air quality data, a meteorological diffusion model is used to compute pollutant concentrations in the ambient air at specified receptor points. The diffusion model is based on the mathematical treatment of pollutant emissions and meteorological data. While inherent limitations in the model are

recognized, its results can be appropriately modified and interpreted to provide reasonable spatial distributions of long-term (seasonal and annual) average pollutant concentrations. The available air quality data in the Boston area has been used as a means of validating the theoretical concentrations computed by the model. A comparison of predicted concentrations with measured values indicated that an adjustment was necessary to the predicted concentrations so that they might conform to measured levels. However, greater reliance has been placed on relative pollutant concentrations in defining the Region than has been placed on the predicted absolute concentrations. Relative concentration distributions identify those areas most affected by urban area pollutant emissions.

The diffusion model is based on the Gaussian diffusion equation, described by Pasquill[1, 2] and modified for long-term averages[3,4] for application to the multiple-source situation typical of an urban complex. The basic equation assumes that the concentration of a pollutant within a plume has a Gaussian distribution about the plume centerline in the vertical and horizontal directions. The dispersion of the plume is a function of the emission rate, effective source and receptor heights, atmospheric stability and the distance from the source. The plume is assumed to move downwind according to the mean wind.

The model was used to predict concentrations of SO_2, CO, and total suspended particulates. The averaging times were the summer and winter seasons and the year. In order that the theoretical

pollutant levels could be determined, it was necessary to evaluate certain meteorological input parameters. These parameters are wind direction and frequency of occurrence in each direction, effective wind speeds for each direction, and mixing depths for various averaging times.

Figure 8 shows the wind roses for the summer, winter, and year for the Boston area*. They represent graphically the frequency of occurrence of the wind from the various compass directions. This data, along with effective wind speeds for the respective compass directions was used as input data to the computerized model. The characteristic prevailing wind directions for each of the seasons, as depicted by the length of the wind rose radials, produce a direct influence over the dispersion of pollutants. This relationship may be observed by correlating the shapes of the concentration isopleths for the pollutants (see Figures 9, 11, and 13) and the wind rose for the appropriate averaging time.

Table IV shows average mixing depths for the winter, summer, and annual seasons**. A significant diurnal variation in the mixing depth is indicated. These mixing depths define the volume of air above the surface through which pollutants are allowed to mix, and are assumed to have no spatial variation (i.e., mixing depth is constant) over the receptor grid system.

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*U.S. Weather Bureau Data for Logan International Airport, Boston, Mass., 1951 through 1960.

**Computed mixing depths documented by Holzworth[5, 6] and by recent tabulations furnished to the Meteorological Program, NAPCA, by the National Weather Record Center, ESSA.

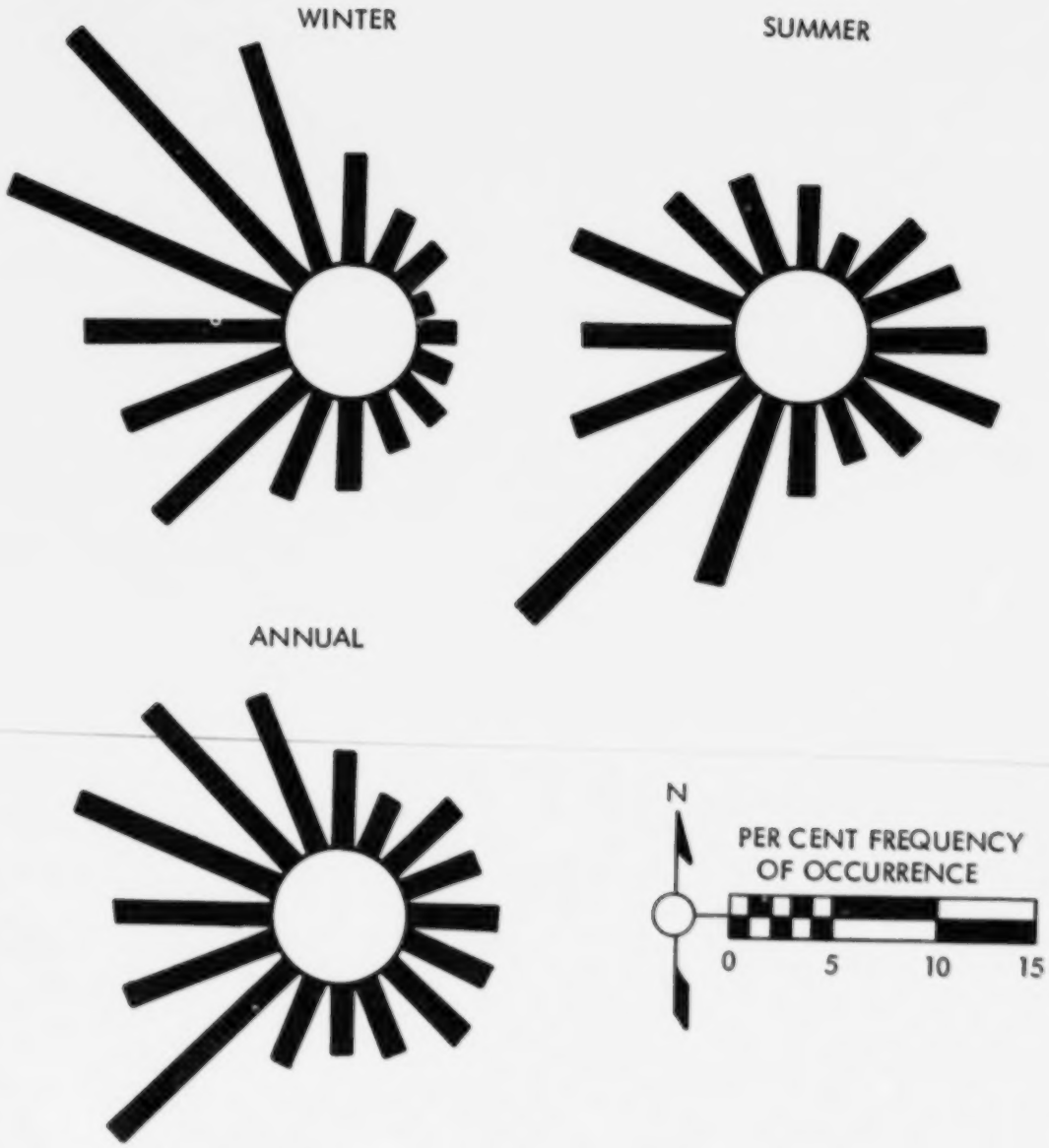

FIGURE 8 . WIND DIRECTION PER CENT FREQUENCY OF OCCURENCE FOR VARIOUS AVERAGING TIMES.

Table IV

Average Mixing Depths for Boston
by Season and Time of Day (meters).

Season	Morning Average	Afternoon Average	Average, Morning and Afternoon
Winter	625	800	712
Summer	390	1300	845
Annual (all four seasons)	529	1050	789

The diffusion model was used to compute the ground level concentrations of pollutants at 225 receptor points. Their locations were defined by an orthogonal grid system with mesh points 15 kilometers apart. This grid, 210 km. on a side, was centered at the State House in the City of Boston. An effective source height of 75 meters was assumed for all pollutant point sources, while topographical features were neglected for area-source emissions and for the 225 receptor points. This partial neglect of source and receptor height considerations can be tolerated since the distances between source-receptor points involved are sufficiently great so as to diminish elevations as a variable for the outer portions of the 210 km. by 210 km. area.

Long term pollutant concentrations have been used in this study as a guide for determining the size of the region. Past experience has shown that the smaller region defined on this basis,

in contrast to a region defined on the basis of more severe but less frequent "episodic" conditions, encompasses a multi-jurisdictional region amenable to regional control efforts. In addition, a reliance has been placed upon existing jurisdictional arrangements (towns) in arriving at the boundaries of the region. This arrangement provides a certain geographical latitude for the diffusion model results. It also tends to reduce the significance of minor diffusion model misestimations insofar as the size of the region is concerned.

Following is a presentation of the results of the diffusion model analysis for the metropolitan Boston area.

Sulfur Dioxide

A known phenomenon associated with the gaseous pollutant sulfur dioxide is its ability to react either photochemically or catalytically with other substances in the atmosphere to form SO_3, sulfuric acid, and acid salts. This is commonly referred to as the "decay" of SO_2 with time. The length of time assumed for the "half-life" of SO_2 is a measure of the rate of decay of that pollutant. Diffusion model results presented here are based on a 3-hour SO_2 half-life.

The predicted SO_2 concentrations for the winter averaging time are shown in Figure 9. The results for the winter averaging time are presented here since the greatest land areas are affected by any given SO_2 concentration contour. This is due to the greater space-heating requirements during the winter. The shape of the isopleths reflect the influence of the winter winds. These winds are primarily directed

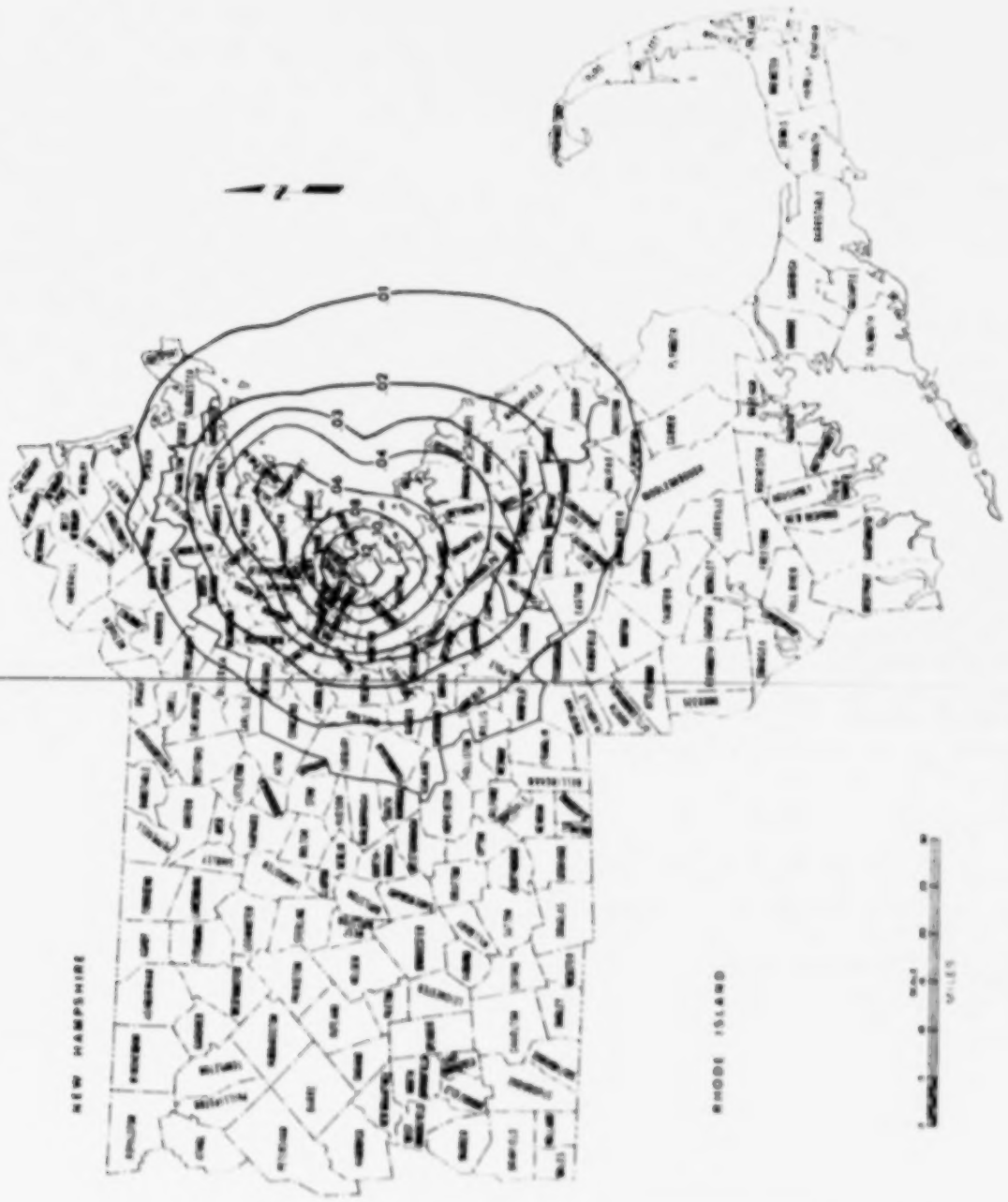

FIGURE 9. THEORETICAL SO_2 CONCENTRATIONS IN PPM:
WINTER AVERAGE (ASSUMED 3. HR. HALF LIFE).

from the northwest and southwest quadrants (see Figure 8). As a result those cities and towns to the northeast and southeast of Boston serve as chief receptors of the pollutant emissions. The relative concentrations show a tendency toward leveling to a constant value beginning at the .02 ppm isopleth. The concentration gradient is less in the vicinity of the .02 ppm contour than at the core of the area where the closely spaced contours appear. The .02 ppm contour is a good indicator of the region whose ambient air is most affected by urban-area source emissions. This contour extends north to Topsfield and Hamilton, west to Wellesley and Weston, and south to Brockton.

The determination of the Region on the basis of relative concentrations---as was done above---places a reliance on the model to predict pollutant dispersion characteristics. If however, a reliance is placed on the model to predict absolute concentrations accurately, then verification of the model by comparison with air quality data is desirable. There exists in the Boston area a limited amount of ambient air quality data, collected by the Air Use Management Section of the Massachusetts State Department of Public Health.[9]

Comparison of SO_2 concentrations, measured at 10 urban sites in or near Boston, with predicted concentrations at these same locations, indicates that the model tends to overestimate measured

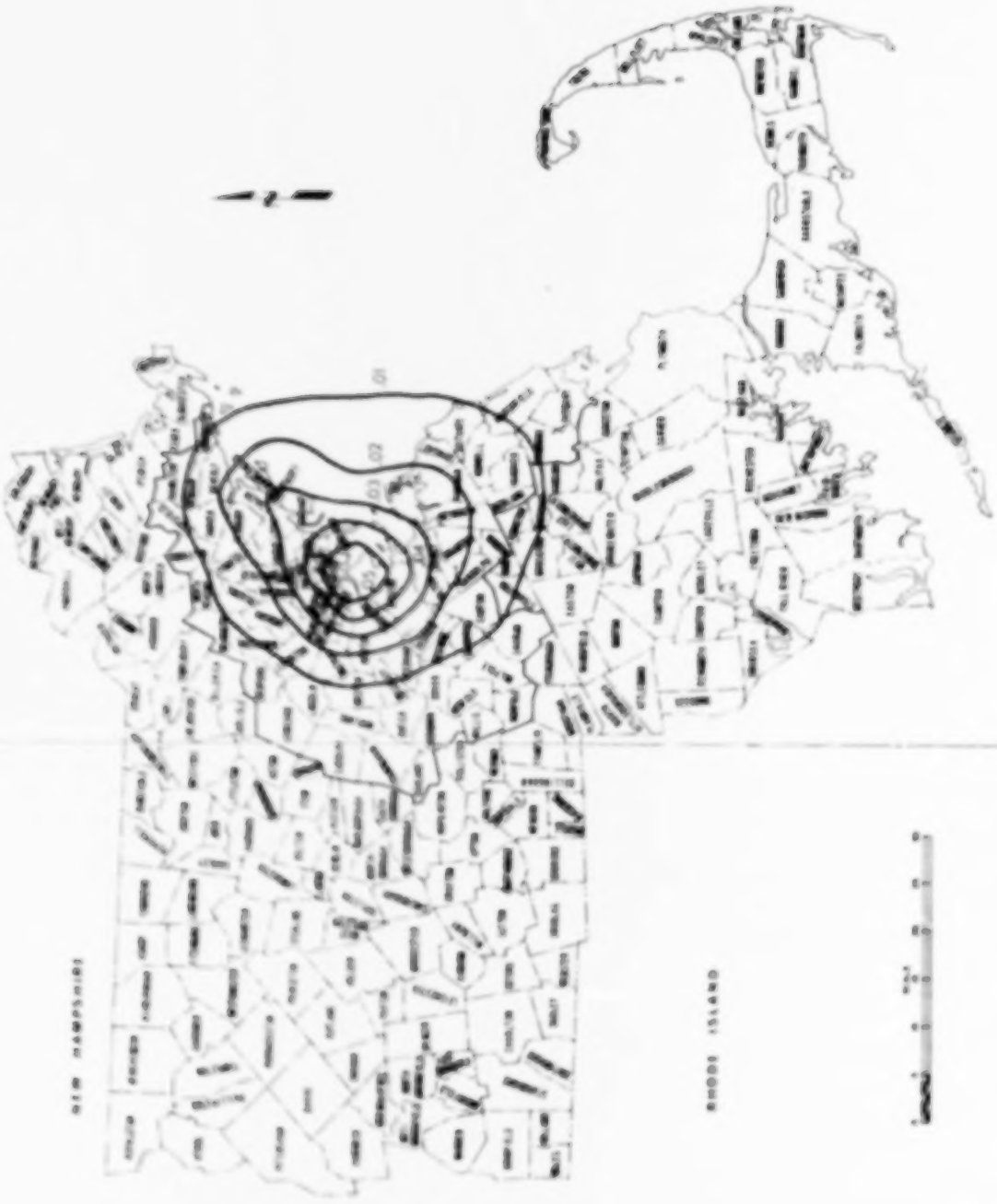

FIGURE 10. ADJUSTED SO_2 CONCENTRATIONS IN PPM; WINTER AVERAGE.

concentrations.* Thus, an average correction factor of 0.46** was applied to the theoretical concentrations. Figure 10 represents the result of this adjustment. The spatial relationship of the contours, and the overall dispersion patterns predicted by the model, are retained in Figure 10. The .01 ppm contour line coincides roughly with the .02 ppm contour of Figure 9. As indicated in Figure 10, it extends north to Hamilton, west to Weston, and south to Brockton.

Suspended Particulates

Figure 11 shows the theoretical suspended particulate concentrations predicted by the diffusion model. The winter averaging time is shown here since the greatest particulate emissions occur during that period, and since the build-up of particulate concentrations in the ambient air affects the greatest land area during the winter. Two distinct centers of high concentrations are shown. One occurs over the city of Boston where dense urbanization harbors a similarly dense conglomeration of particulate emission sources. The other exists northeast of the city of Boston, reflecting the existence of a large, predominantly coal burning, power plant. The influence of this source may tend to be distorted by the model since the assumed effective stack height of 75 meters is not representative of this power plant.

*Sampling measurements averaged for the winter season were collected during January and February, 1966. Diffusion model concentrations were computed using meteorological data for the months of January, February, and March; emissions input data is for the year 1967.

**This average correction factor is assumed to be valid over the entire receptor grid, though the factor was derived from concentration comparisons near the center of the grid only.

FIGURE 11. THEORETICAL SUSPENDED PARTICULATE CONCENTRATIONS IN $\mu g/m^3$: WINTER AVERAGE

The spatial relat onship of the contours indicates that the tendency to a constant concentration level occurs at the 15 $\mu g/m^3$ concentration contour. Here the concentration gradient exhibits a distinct decrease as one travels further outward from the core area. Hence, it might be said that the atmosphere over the area enclosed by the 15 $\mu g/m^3$ concentration contour is that most heavily burdened by the inventoried source emissions. This area extends northward to Hamilton, west to Newton and Waltham, and south to Brockton.

The identification of the area in this manner places a reliance on the diffusion model to predict relative concentrations only, and to indicate pollutant dispersion patterns. This eliminates the need to equate predicted concentrations to measured particulate concentrations where such a gross simplification would no doubt be misleading. Air quality data does exist, however, in the core of the area. Comparison of measured data[9] at 20 sampling stations* with predicted concentrations at these same locations indicated that the measured concentrations exceeded those predicted by an average factor of 2.35. It is assumed that this correction factor is valid for adjusting predicted concentrations over the entire extent of the receptor grid. Figure 12 represents the adjusted theoretical concentrations.

A review of available air quality data[10,11,12] for suspended particulates has shown that an approximate level of 30 $\mu g/m^3$ can be

* Data collected during January and February 1966.

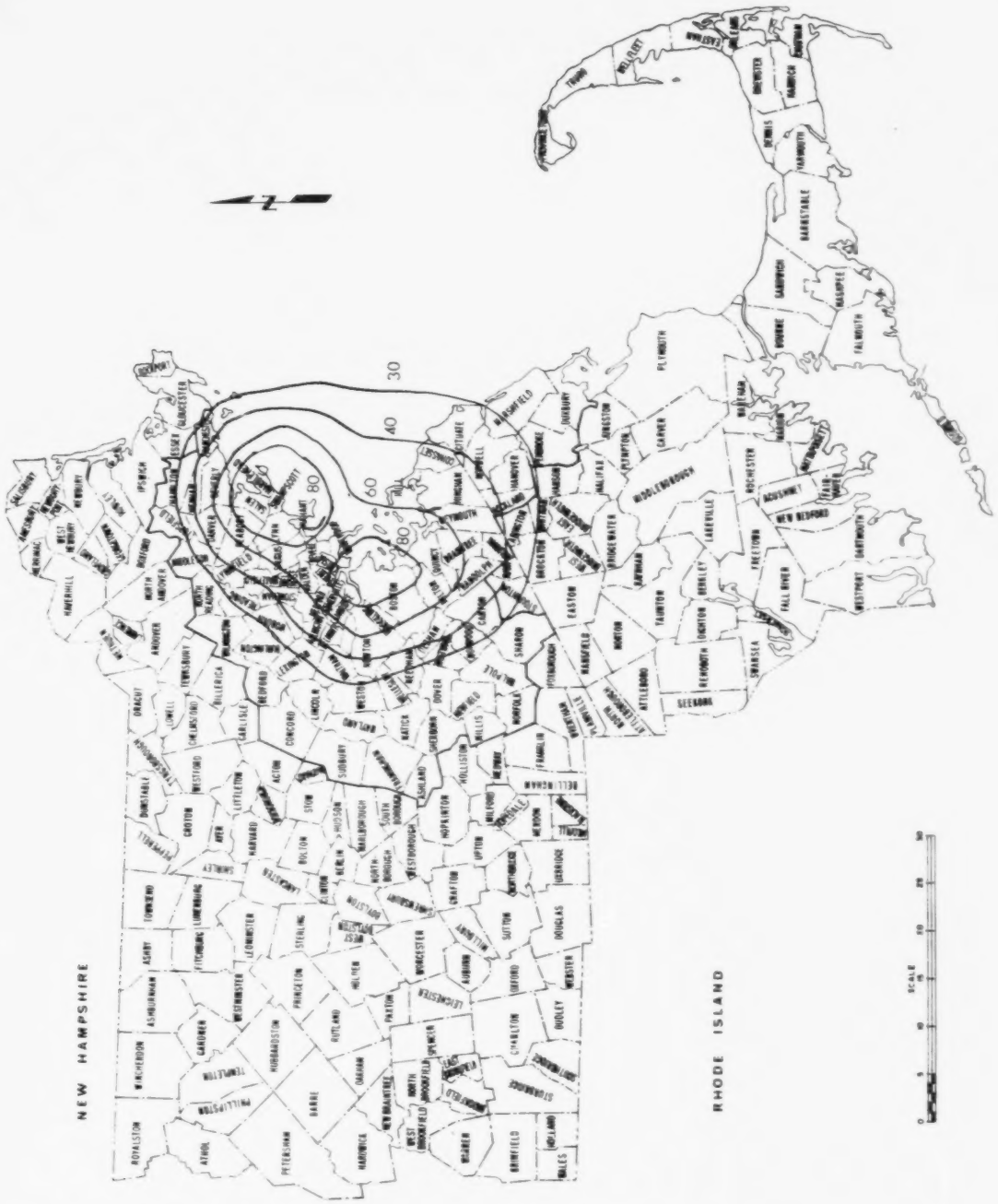

FIGURE 12. ADJUSTED SUSPENDED PARTICULATE CONCENTRATIONS IN $\mu g/m^3$; WINTER AVERAGE.

regarded as the normal background concentration* in the metropolitan Boston area. This represents an average of yearly geometric means taken from sampling stations in the several States bordering Massachusetts.** The sampling at these stations occurred in the years 1959, 1961, and 1963 through 1967.*** For this reason, the adjusted concentrations were carried out to a concentration of 30 $\mu g/m^3$. The area included within this isopleth closely approximates the 15 $\mu g/m^3$ isopleth in Figure 11. The 30 $\mu g/m^3$ contour reaches south to Brockton, north to Hamilton, and west to Waltham and Weston. This was the boundary where relative concentrations began to noticeably level off.

Carbon Monoxide

Figure 13 shows the theoretical concentrations of carbon monoxide pollution predicted by the diffusion model. The results are for the winter averaging time since the greatest emissions occur during that period. The influence of any major point source is not visually evident since the primary emitter of this type of pollution is the automobile, treated as an area source.

The predicted concentration gradient for carbon monoxide falls off rapidly from the core to the 0.10 ppm isopleth. Indications are

* This includes particulate pollution from natural sources and from nearby urban centers.

** Stations located in the States of New York, Connecticut, Rhode Island, Vermont, New Hampshire, and Maine.

*** Air Quality data for 1966 and 1967 was obtained from the National Air Quality Data Bank, National Air Sampling Network (NASN).

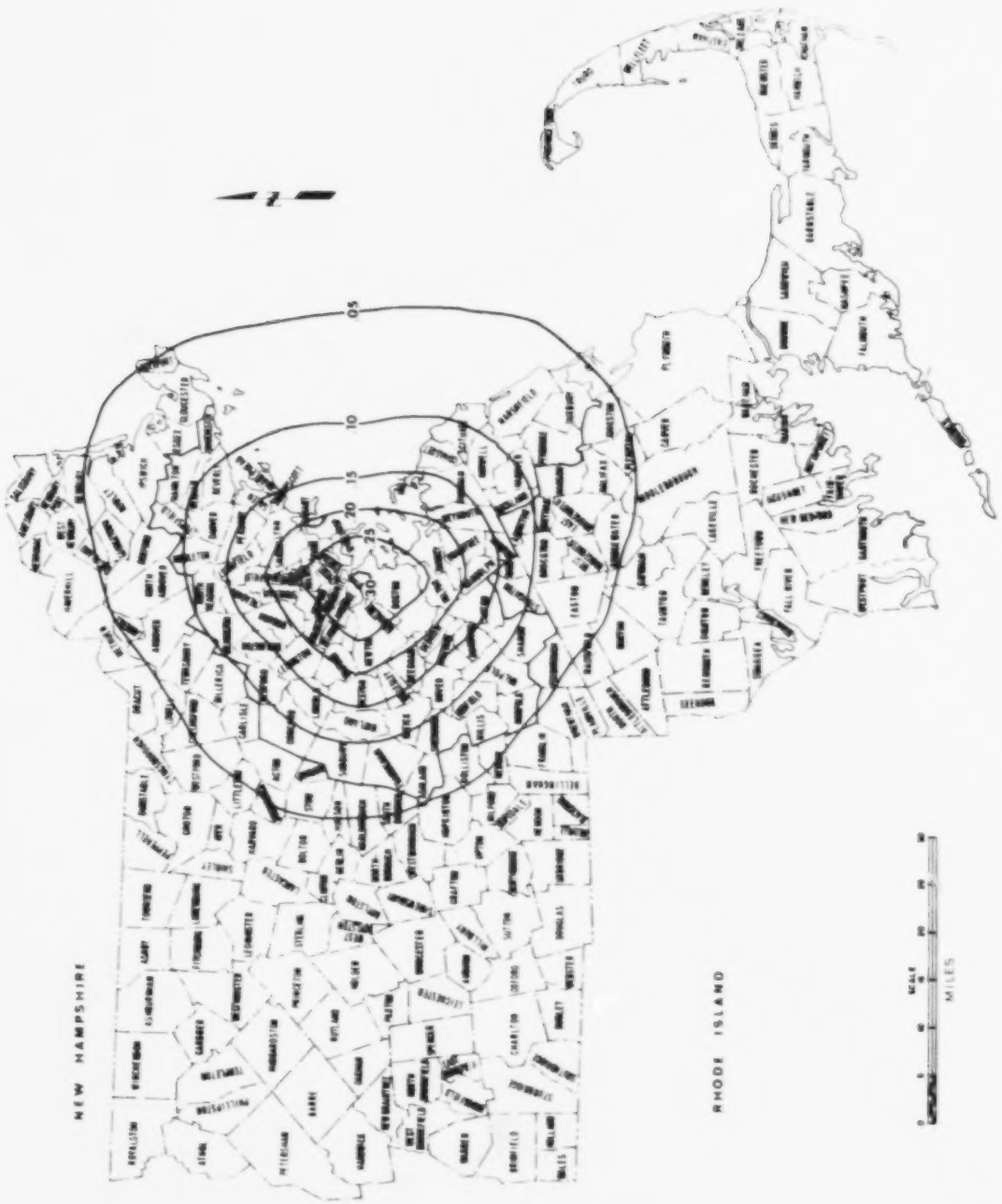

FIGURE 13. THEORETICAL CARBON MONOXIDE CONCENTRATIONS IN PPM: WINTER AVERAGE.

that the urban area emissions have the greatest relative effect on a region extending north to Middleton and Topsfield, west to Framingham, and south to Brockton. This corresponds roughly to the same area significantly affected by SO_2 (Figure 9) and suspended particulate (Figure 11) pollution.

Past analyses in other urban areas have proven that the model generally tends to underestimate actual CO concentrations in the ambient air*. However, no attempt has been made to correlate measured data with the predicted values since few actual air quality measurements have been taken. Nevertheless, it is believed that a certain reliability can be placed on the model for predicting relative CO concentration distributions, particularly at the fringe areas. On this basis, the outlying jurisdictions mentioned above define the limits of the region whose ambient air quality is most affected by CO emissions.

* In past studies correction factors ranging from 3.4 to 5.0 have been applied to the predicted concentrations to bring them in agreement with air quality data. The underestimates are assumed to be the result of the diffusion model's neglect of the built-up nature of an urban area (it therefore assumes more volume for CO diffusion than is the actual case) coupled with the fact that most measurements occur at locations proximate to nearby streets. The diffusion model, however, distributes the contributions of CO from individual streets over the entire urban area.

EVALUATION OF URBAN FACTORS

Section 107 (a) (2) of the Air Quality Act of 1967 calls for the designation of air quality control regions "based on jurisdictional boundaries, urban-industrial concentrations, and other factors...necessary to provide adequate implementation of air quality standards." The designation of air quality control regions must be based on a consideration of existing cooperative regional arrangements, existing State and local air pollution control legislation, and also patterns and rates of urban growth. These considerations, referred to as "urban factors," lead to the establishing of two chief conditions to be met if an air quality control region is to prove effective as a basic tool to an overall air resource management program. First, the boundaries of a region should encompass those locations where projected urbanization will create significant air pollution problems in the foreseeable future. Second, the boundaries should be chosen in a way which is compatible with and fosters unified and cooperative governmental administration of the air resource throughout the region.

A close look at the anticipated character of urbanization in the Boston area requires first, that we limit ourselves to those municipalities felt to develop physically, socially, and economically as a result of regional or multi-jurisdictional interaction. Such interaction suggests that these municipalities should be included in the Region in order that the most effective administration of an air resource management program will occur. A review of those cities and towns involved in the past, or at present, in regional planning

efforts, will help us to define initially a cohesive yet inclusive "metropolitan Boston" area.

Figure 14 represents a map of 6 Standard Metropolitan Statistical Areas (SMSA's) or portions of SMSA's* in Eastern Massachusetts. By definition, SMSA's serve to identify an economically and socially integrated group of communities. They also serve as a geographic base for the gathering of statistical data. Brockton, Lawrence, Lowell, and Worcester are center cities for SMSA's which surround the Boston Standard Metropolitan Statistical Area. These center cities, as well as the peripheral cities and towns included in each SMSA, are indirectly dependent on metropolitan Boston as a basic employment and trading area. The Worcester SMSA is separated from the Boston SMSA by a corridor one town wide at its narrowest section, while the Lawrence, Lowell, and Brockton SMSA's are directly adjacent to the Boston SMSA. The Providence SMSA abuts the Boston SMSA, though only the Massachusetts portion is shown in the figure.

The limits of the Boston SMSA define the smallest logical study area for the purpose of this evaluation. This area comprises the cities and towns most closely allied with Boston. The sole inclusion of these communities in the Region would facilitate a future control program on the basis of the wealth of statistical data that has been accumulated. It would be somewhat shortsighted, however, to neglect to consider areas beyond this SMSA since it has been mentioned that

*Portions of the Lawrence-Haverhill SMSA extend into New Hampshire.

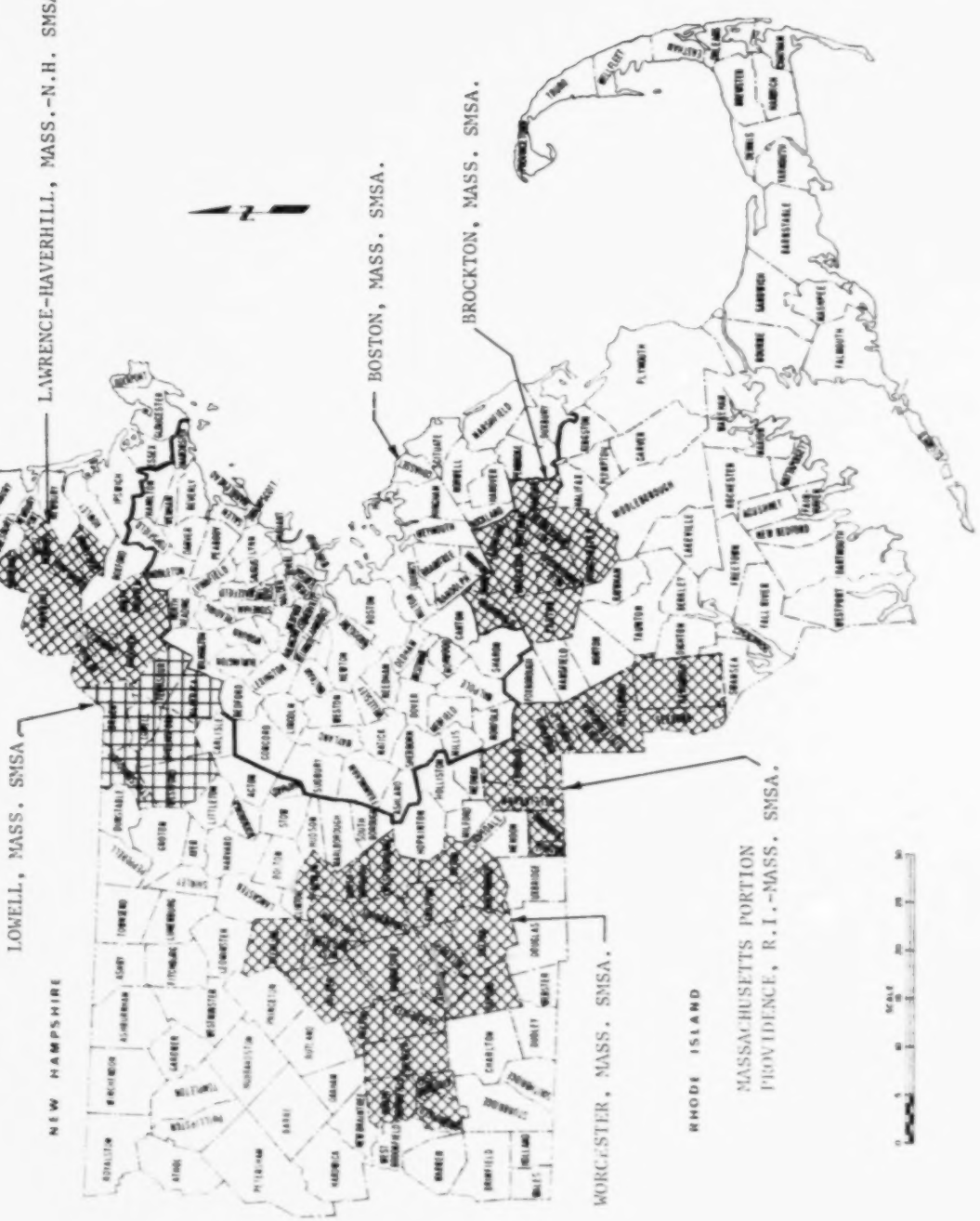

FIGURE 14. STANDARD METROPOLITAN STATISTICAL AREAS IN EASTERN MASSACHUSETTS.

future urbanization is to be considered.

Figure 15 identifies the region encompassed by the Eastern Massachusetts Regional Planning Project (EMRPP), formerly known as the Boston Regional Planning Project. The EMRPP includes 152 cities and towns and was organized in 1962 on an interagency basis by the State Department of Public Works, the Metropolitan Area Planning Council (MAPC), and the State Department of Commerce and Development. The EMRPP was established to develop comprehensive land use and transportation planning, a prerequisite for Federal aid to highways in urban areas. This region contains peripheral cities and towns physically and economically remote to the City of Boston.

Figure 15 also shows 114 contiguous cities and towns comprising the "metropolitan Boston area"--an area defined by the Massachusetts Department of Commerce and Development in their 1966 Interim Definition of Regions for the purpose of facilitating regional organization. This was identified as a logical planning region in Eastern Massachusetts. In April, 1968, the Metropolitan Area Planning Council published a population projection study[14] for a region* closely approximating that given by the Interim Definition.

Figure 16 identifies the jurisdictions encompassed by the various planning agencies within or abutting the EMRPP region. The central shaded portion represents the 97 member communities** of the Metropolitan

*Includes all cities and towns given by the Interim Definition except that the town of Bolton is included in the study while Kingston, Carver, Plympton, and Plymouth are excluded.
**Member communities as of June, 1968.

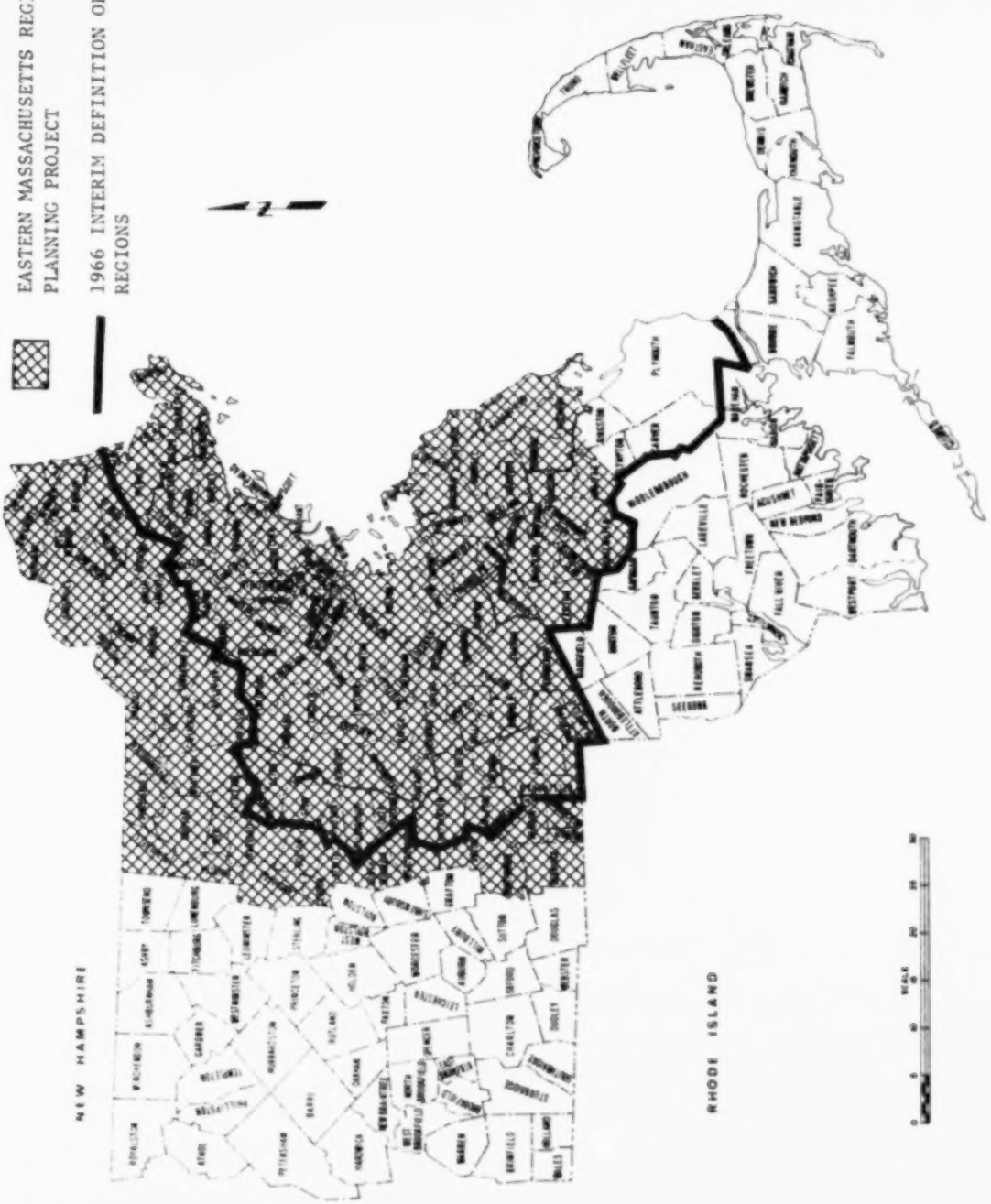

FIGURE 15. PLANNING REGIONS IN EASTERN MASSACHUSETTS.

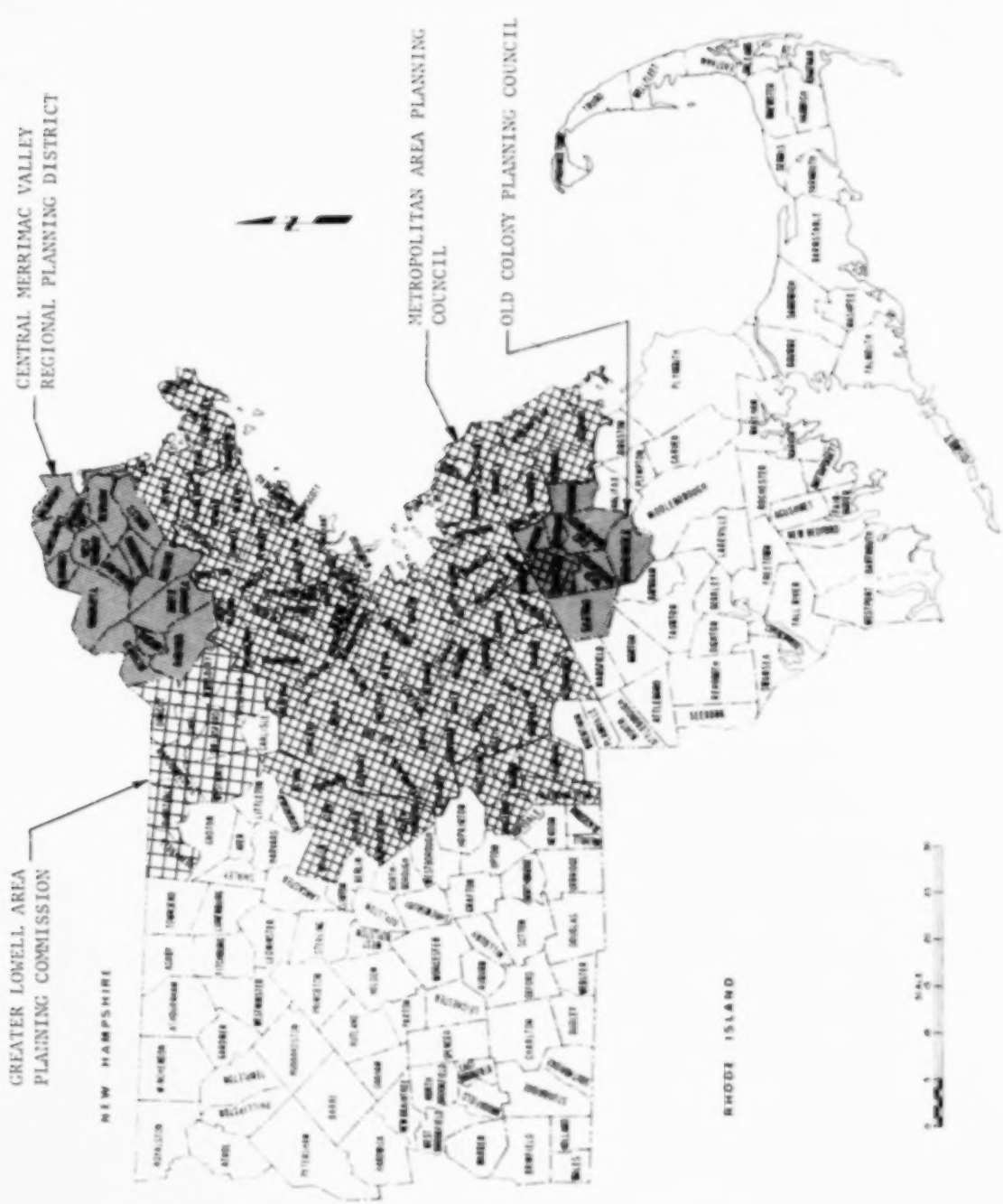

FIGURE 16. BOUNDARIES OF PLANNING AGENCIES IN EASTERN MASSACHUSETTS.

Area Planning Council. The MAPC was organized in 1964, and at that time was given responsibility by the State Legislature for conducting research and compiling data necessary to improve the physical, social, and economic conditions within its planning district. The MAPC receives an annual appropriation from the State Legislature which is paid for on a per capita basis by the member communities. Membership in the MAPC is open to any city or town immediately adjacent to the present district.

It is noteworthy that the City of Brockton is a member of both the MAPC and the Old Colony Planning Council (OCPC). The OCPC includes all the Brockton SMSA communities with the exception of Stoughton. The 1966 Interim Definition of the metropolitan Boston area includes all member communities of the OCPC and the Brockton SMSA within its boundaries, while no jurisdictional entities from the Lawrence and Lowell SMSA's are so included. It is clear that Brockton, and therefore its neighboring cities and towns have been allied with the City of Boston in the past for planning purposes.

Lawrence and Lowell, are the core cities for planning agencies in their respective areas. The boundaries of these planning agencies, shown in Figure 16, abut the outer limits of the MAPC.* The EMRPP area included all or part of the jurisdictions of these two planning agencies, along with the Metropolitan Area Planning Council

*Three additional planning agencies abut the MAPC. These are the Central Massachusetts Regional Planning Commission to the west, the Southeastern Massachusetts Regional Planning Commission, and Rhode Island Development Council to the south. Member communities of these agencies were not considered for inclusion in the Region due to their geographic and socio-economic remoteness from the Boston metropolis.

and the Old Colony Planning Council. Nevertheless, the communities within the jurisdiction of the Central Merrimac Valley Regional Planning District and the Greater Lowell Area Planning Commission will not be considered for inclusion in the Region at this time. These areas possess loose social and economic ties with Boston, and have lacked inclusion in any regional planning efforts aimed at their overall integration with metropolitan Boston. The inclusion of these areas in a region of their own may be necessary at a later date, owing to the magnitude of the pollution problem, a problem distinct from that of metropolitan Boston.

Based on the above arguments, the outer bounds of the area encompassed by the MAPC and the OCPC identifies the municipalities to be considered for inclusion in the Region at this time. The following study of the trends toward urbanization in the area will determine whether the Region should be lesser in extent than the combined area of these two planning agencies.

Figure 17 shows the population distribution for the jurisdictions within the MAPC and OCPC based on figures from the 1965 Massachusetts State Census. This 1965 population density map shows a corridor of high population extending west to Framingham and south to Brockton. A ring of municipalities of high population density extending north to Burlington, Reading, and Beverly also exists. Correlation of the present population distribution with Figure 20 reveals that the areas of high population density outward from Boston follow roughly the patterns of the existing major circumferential and radial highways

KEY:

POPULATION DENSITY
(PERSONS/SQUARE MILE)

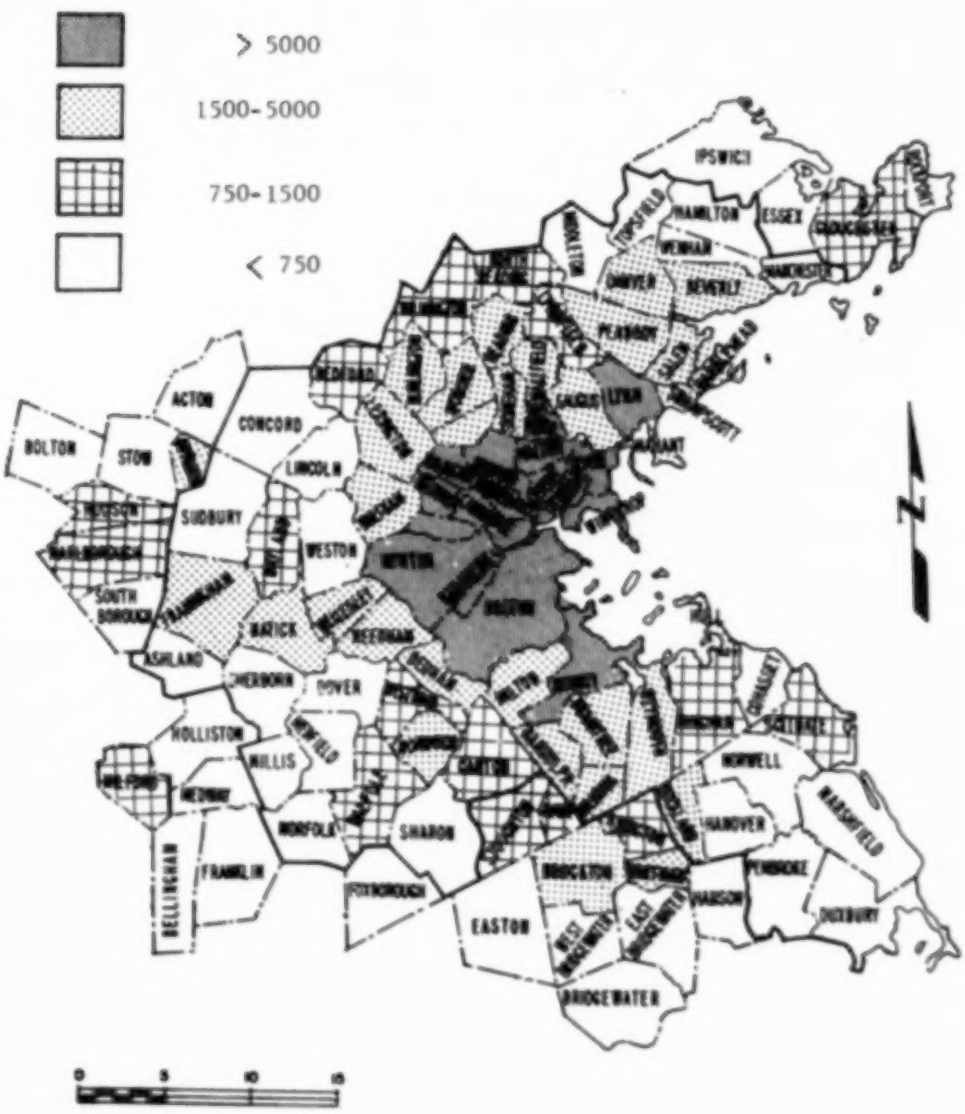

FIGURE 17. 1965 POPULATION DENSITY.

in the region (e.g., Routes 9 and I-90 to the west, 24 to the south, and circumferential routes 128 and 495).

Figure 18 depicts 1990 predicted population densities.[14] Figure 19 indicates the municipalities where greatest growth (1965-1990) is projected to occur, in terms of additional residents per square mile. This figure shows the trend toward little growth, and sometimes a population loss, in the core of the region. Observations in Boston and other cities have led to the theory that population growth occurs in a ripple-like pattern outward from the center (Boston). Figure 19 reflects this to an extent, though distortions created by topography and by the highway systems are evident. The ten communities projected to have a population increase of between 25 and 50% between 1960 and 1990 lie in a ring on route 128. The existence of route I-495 and a proposed circumferential highway between it and route 128 will tend to carry this uniform growth pattern further out to the north, west, and south of Boston.

Further review of Figure 20, the 1990 proposed highway network, shows that a comprehensive system of belt and radial arteries will tie the outer portions of the area to the core city, but at the same time this extensive system will promote greater traffic volumes. Auto ownership in the Boston area is expected to increase at a rate greater than either population or employment. Along with this increase in traffic volume will be a concommitant increase in carbon monoxide emissions. The geographic patterns of the major highways in the area are in a way reflective of the spatial emission pattern of carbon

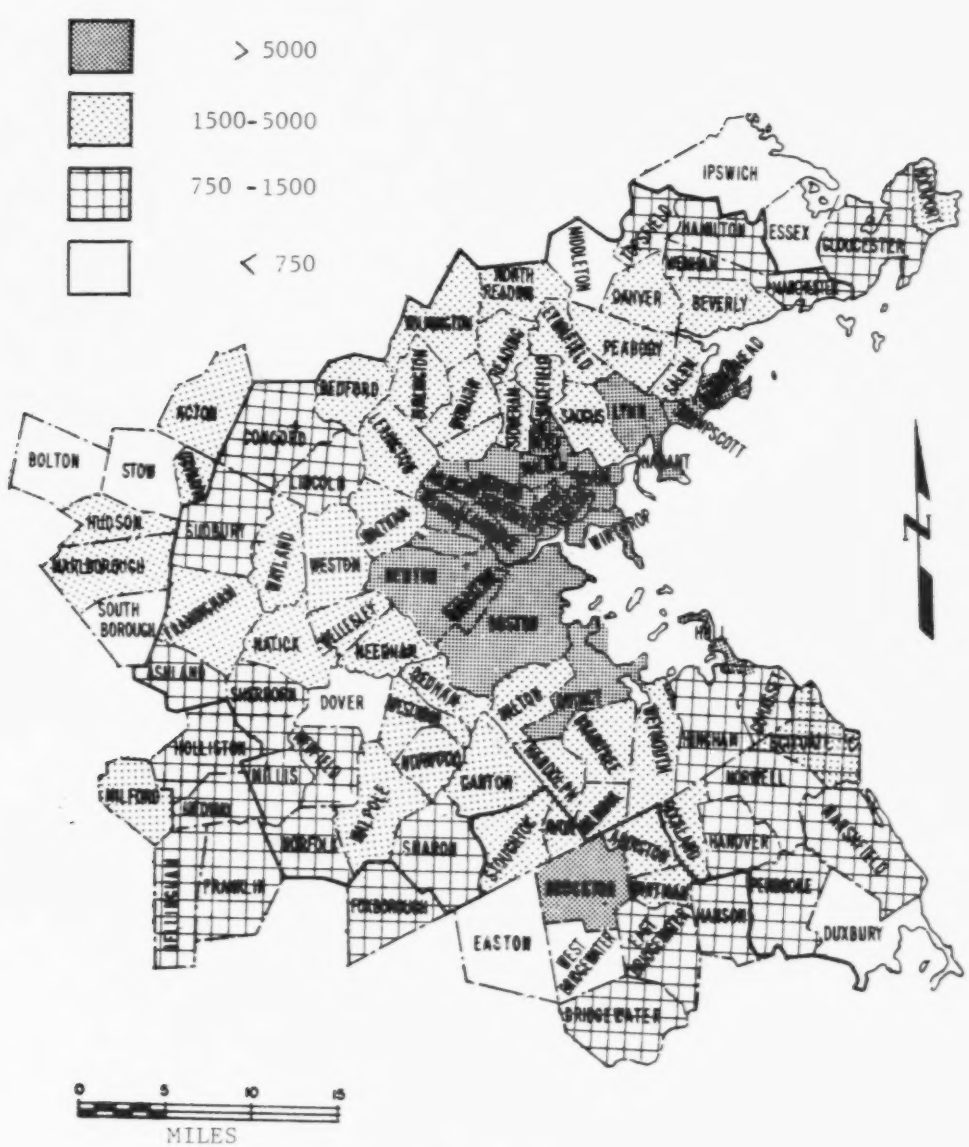

FIGURE 18. 1990 PROJECTED POPULATION DENSITY.

KEY:

ADDITIONAL RESIDENTS
(PERSONS/SQUARE MILE)

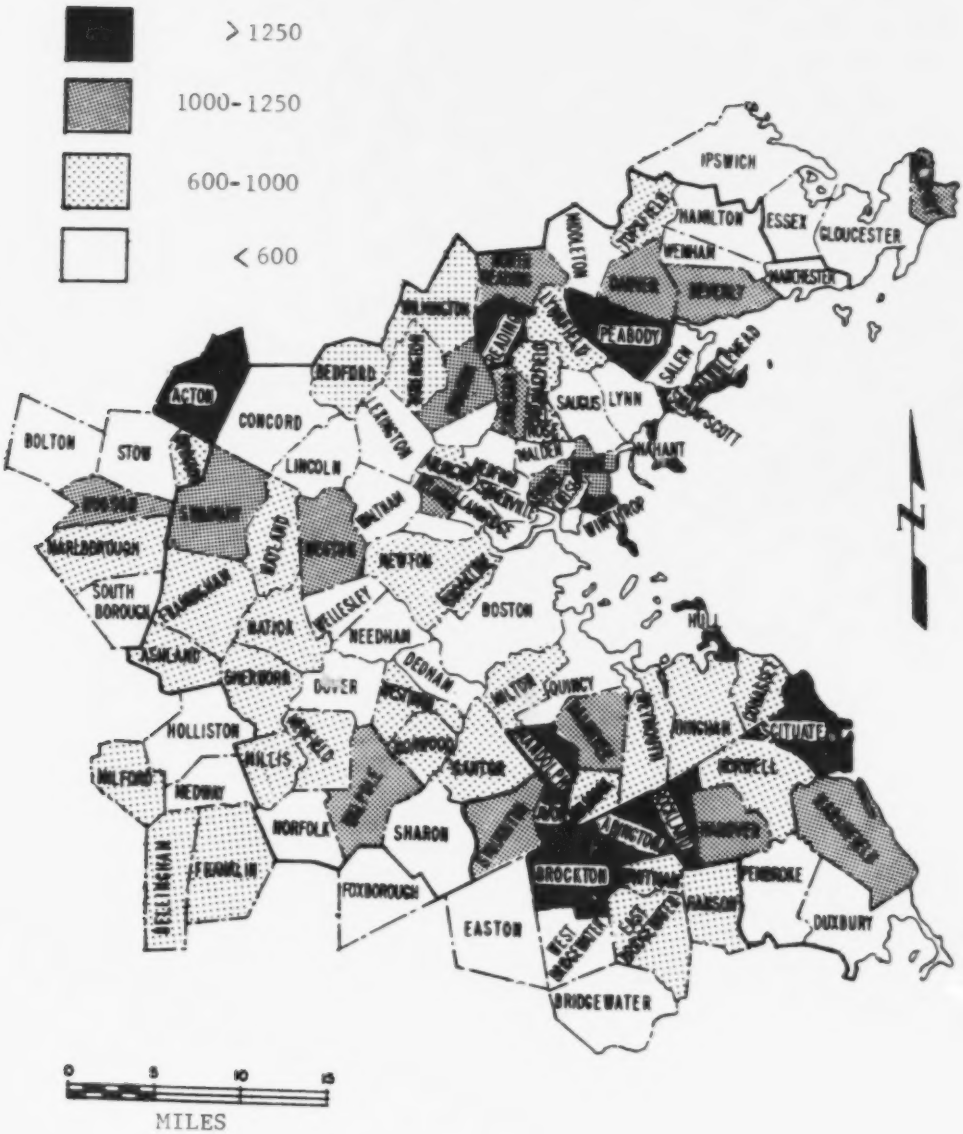

FIGURE 19. 1965-1990 PROJECTED ADDITIONAL RESIDENTS PER SQUARE MILE.

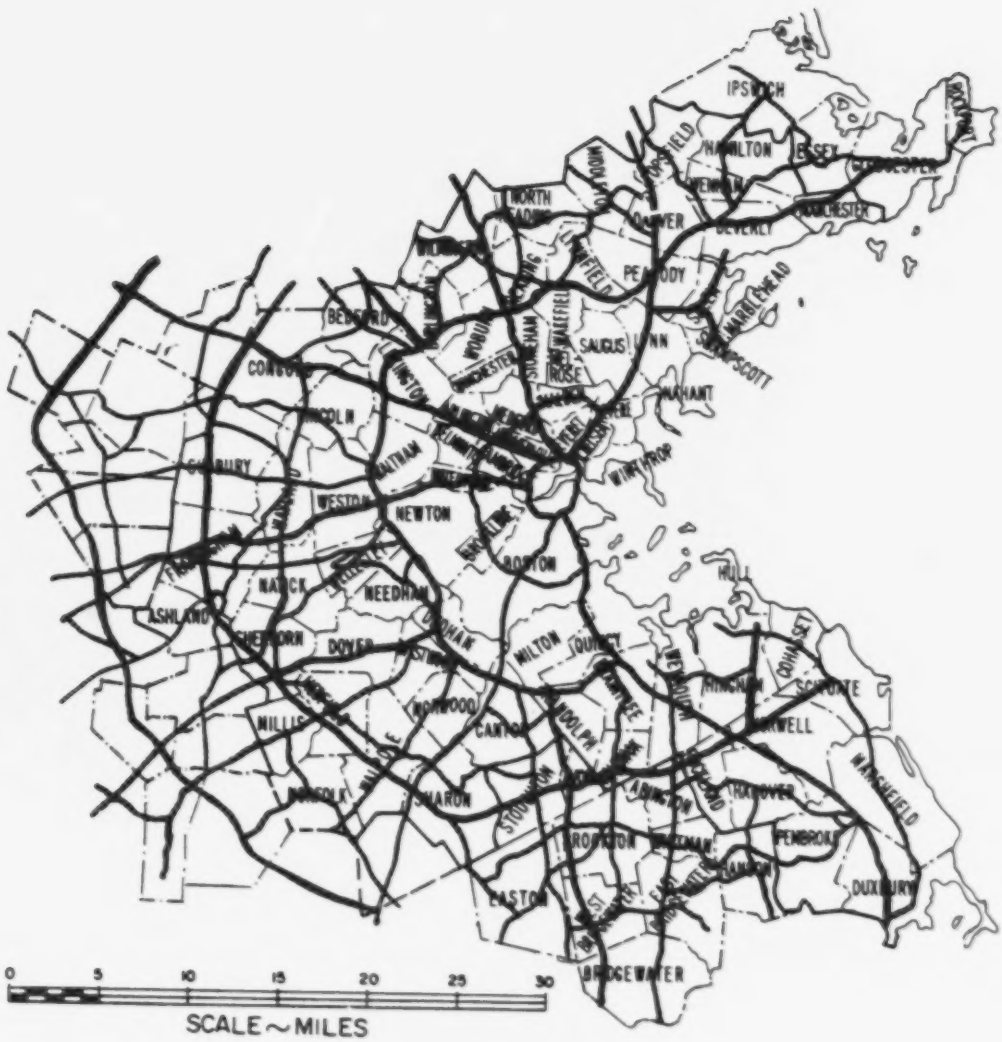

FIGURE 20. 1990 PROPOSED HIGHWAY NETWORK

monoxide since the automobile can be held accountable at present for 89% of all CO emissions in the Boston area.

Figure 21 shows the projected residential density pattern for new development. This pattern parallels the 1990 population density distribution. Figure 22 shows existing and proposed (1990) regional and sub-regional centers for the metropolitan area. This figure pinpoints areas that are or will become major employment centers. A comparison of this figure with Figure 20 shows that the majority of these centers lie immediately adjacent to the major existing and projected expressways.

The third condition to be met by the Region is that it be compatible with and foster the development of effective governmental administration of a regional air quality control program. This involves a review of the existing air pollution programs in metropolitan Boston, especially those responsible for the regional control of air pollution.

The Massachusetts Department of Public Health became actively involved in air pollution control in 1954 when the State Legislature transferred the Division of Smoke Inspection from the Department of Public Utilities to the Department of Public Health. At the same time the Division of Smoke Inspection was placed under the Division of Sanitary Engineering within the Department of Public Health. The Legislature authorized the Department of Public Health to adopt (minimum) State-wide air-pollution regulations. The application of such regulations was intended for air pollutant emissions

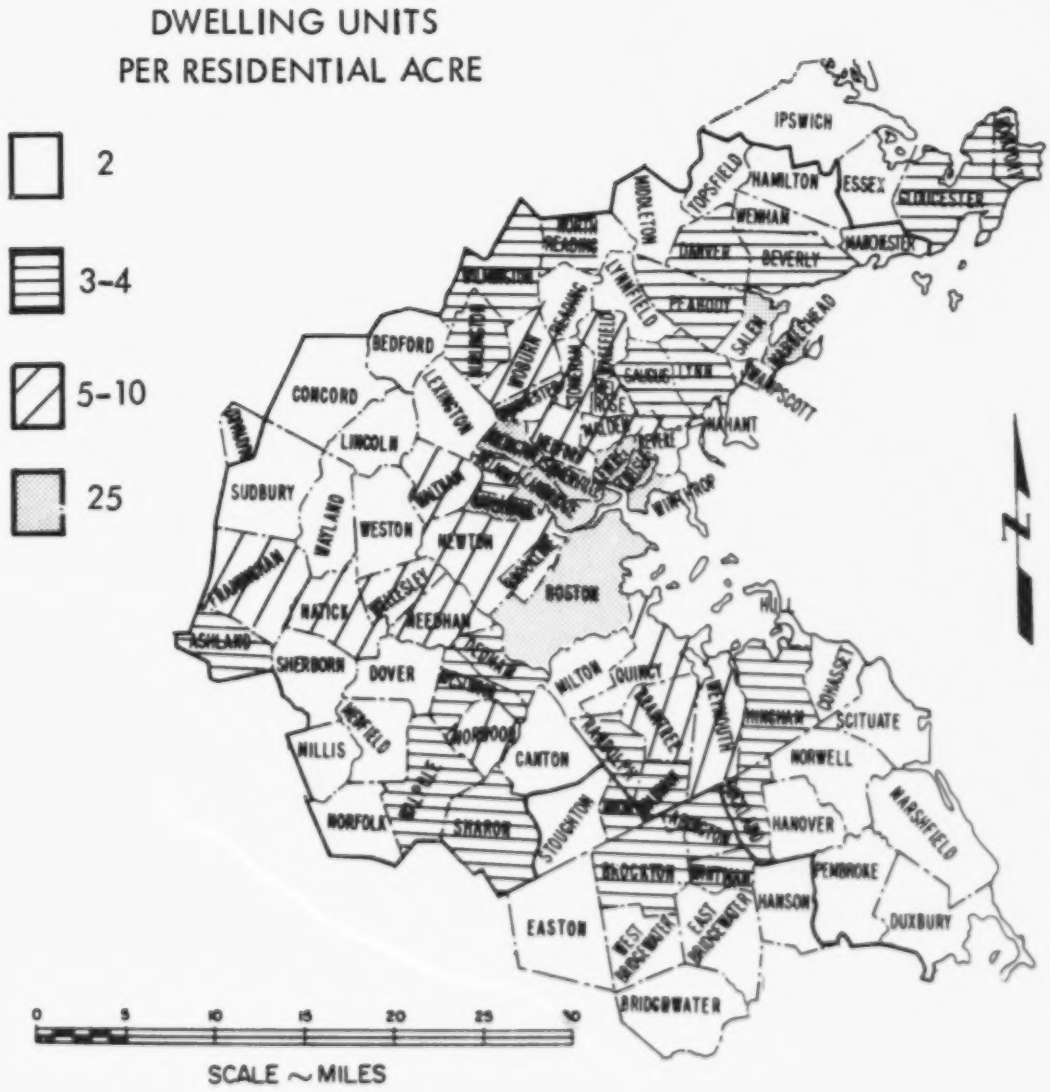

FIGURE 21. PROJECTED 1990 RESIDENTIAL DENSITY PATTERN FOR NEW DEVELOPMENT.

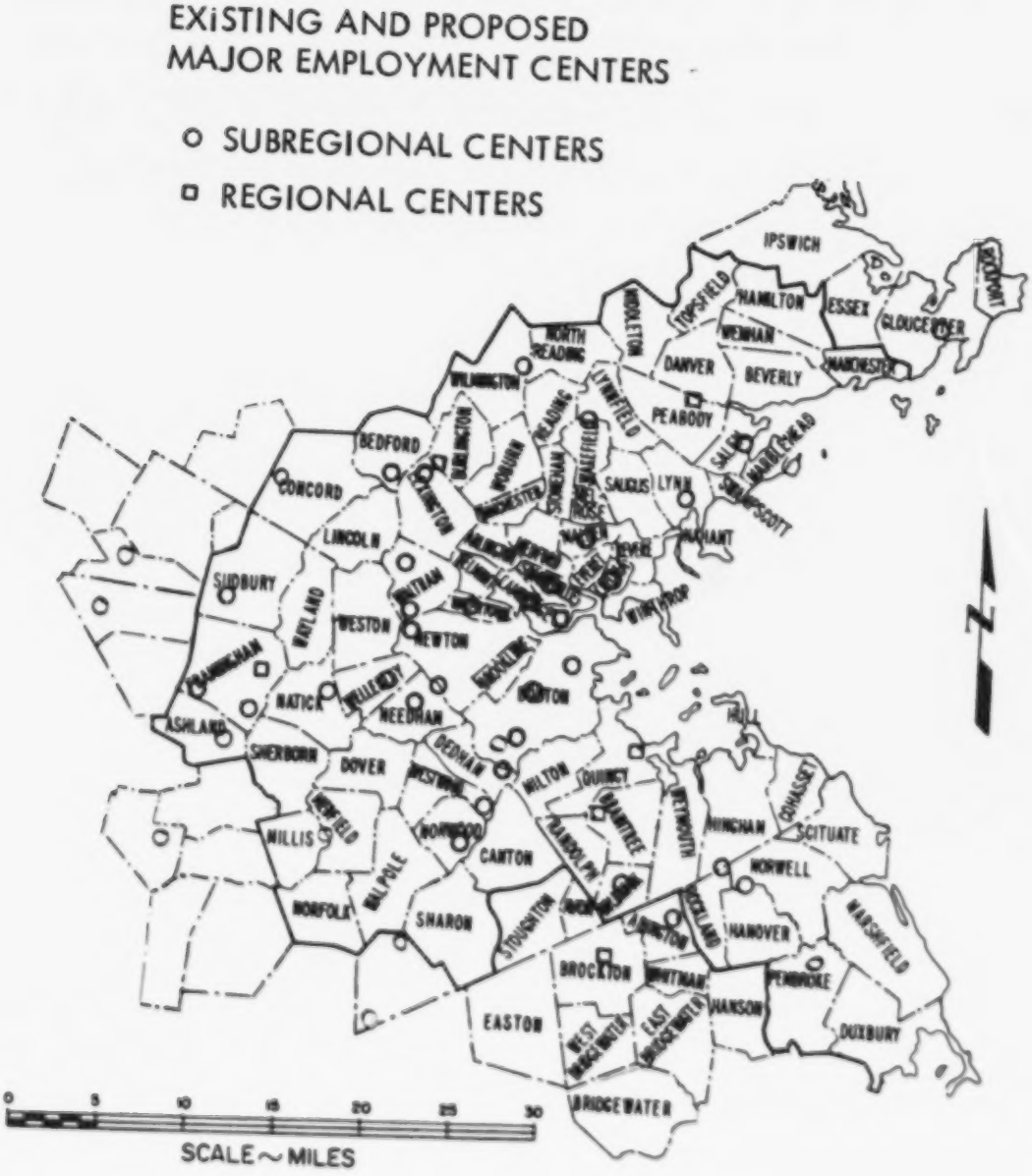

FIGURE 22. EXISTING AND PROPOSED (1990) REGIONAL AND SUB-REGIONAL CENTERS.

arising from State institutions, mobile sources, sources causing inter-municipal pollution effects, and sources which could and should be controlled by other agencies, but are not.

Existing law gives local boards of health the authority to adopt air pollution rules and regulations with the approval of the Department of Public Health. In the metropolitan area, local air pollution programs exist in the cities of Brockton, Beverly, and Salem, and in the town of Natick.

Legislation passed in 1960 established the Metropolitan (Boston) Air Pollution Control District (MAPCD). The MAPCD is composed of Boston and 29 contiguous cities and towns, and became effective January 1, 1961. The law provided for a comprehensive air pollution control program for metropolitan Boston to be administered by the Division of Sanitary Engineering for the State Department of Public Health. Under this law the State was given authority to regulate all sources of atmospheric pollution within the MAPCD. The boundaries of the MAPCD, which encompasses 320 square miles and over two million people are shown in Figure 23. Other contiguous cities and towns may be admitted to the MAPCD by the Department of Public Health upon application. The MAPCD draws funds from member cities and towns, one half in proportion to population, and one half in proportion to assessed valuation.

Enabling Legislation, also passed in 1960, authorized the Department of Public Health to establish multi-municipal regional air pollution control districts similar to the MAPCD upon the request of two or more contiguous municipalities in the Commonwealth. In 1967

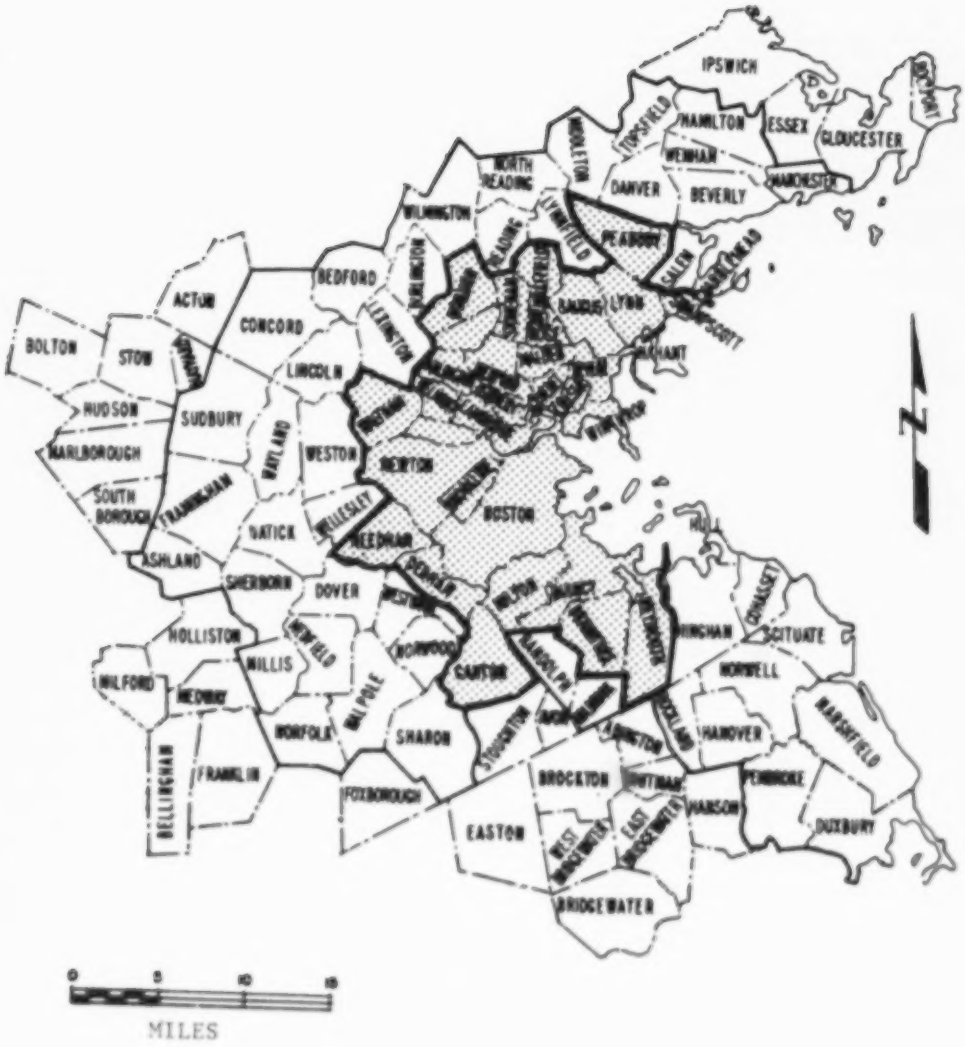

FIGURE 23 . THE METROPOLITAN (BOSTON) AIR POLLUTION CONTROL DISTRICT (MAPCD).

the Lower Pioneer Valley Air Pollution Control District was established following the voluntary request of 10 cities and towns in the Springfield area. The State Department of Public Health continues to encourage the formation of more regional districts in the State. The need for such districts in several areas, including the Merrimac Valley (Lawrence and Lowell areas) has been propounded by state air pollution control officials.[15,16] In addition, a goal of the State is to more fully "cooperate with the Federal Government, where indicated, in such matters as... air region programs and interstate problems."[15] The value of a regional approach to air pollution control in metropolitan Boston is recognized by both the State and Federal governments.

The Metropolitan Air Pollution Control District has in the past proven to be the basis for a sound approach to region-wide air pollution control. It has been effective in causing the cessation of pollutant emissions from a variety of source types within its jurisdiction. With the forthcoming issuance by the Federal government of air quality criteria, acceptable standards may be set for the subsequent abatement and control of gaseous pollutant emissions as well as for visible particulate (smoke) emissions.

A federally designated air quality control region larger than the present MAPCD would probably lessen, though not completely eliminate, the boundary problems normally encountered by a regional control agency. Major sources located immediately outside the present District

would be included in a larger Region. These source-receptor problems then, should be given fullest consideration in determining the Region. As a result, it may become necessary to consider a greater area than does the existing regional arrangements (the MAPCD) in order to more effectively administer the air resource.

THE PROPOSED REGION

Subject to the scheduled consultation, the Secretary, Department of Health, Education, and Welfare, proposes to designate an air quality control region for the metropolitan Boston intrastate area consisting of the following 20 cities and towns:

Cities

Beverly
Boston
Brockton
Cambridge
Chelsea
Everett
Gloucester
Lynn
Malden
Marlborough
Medford
Melrose
Newton
Peabody
Quincy
Revere
Salem
Somerville
Waltham
Woburn

Towns

Abington
Acton
Arlington
Ashland
Avon
Bedford
Belmont
Braintree
Bridgewater
Brookline
Burlington
Canton
Cohasset
Concord
Danvers
Dedham
Dover
Duxbury
East Bridgewater
Easton
Essex
Foxborough
Framingham
Hamilton
Hanover
Hanson
Hingham
Holbrook
Hudson
Hull
Ipswich
Lexington
Lincoln
Lynnfield
Manchester
Marblehead
Marshfield
Maynard
Medfield
Middleton
Millis
Milton
Nahant
Natick
Needham
Norfolk
North Reading
Norwell

(Towns (cont.)

Norwood
Pembroke
Randolph
Reading
Rockland
Rockport
Saugus
Scituate
Sharon
Sherborn
Southborough
Stoneham
Stoughton
Sudbury
Swampscott
Topsfield
Wakefield
Walpole
Watertown
Wayland
Wellesley
Wenham
West Bridgewater
Weston
Westwood
Weymouth
Whitman
Wilmington
Winchester
Winthrop

Figure 24 shows the boundaries of the proposed Region while Figure 25 indicates the geographic relationship of the Region to the surrounding areas.

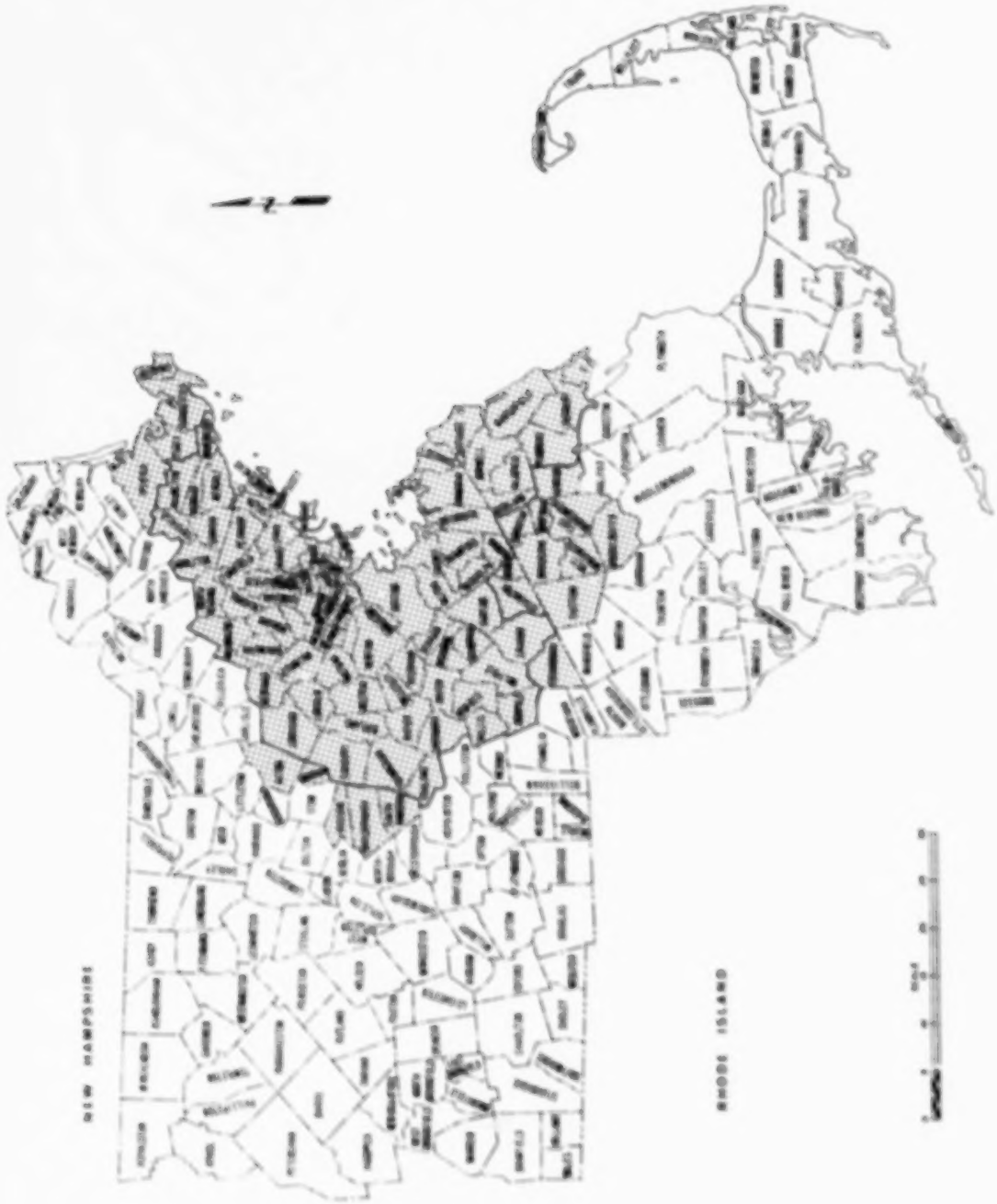

FIGURE 24. PROPOSED METROPOLITAN BOSTON INTRASTATE AIR QUALITY CONTROL REGION.

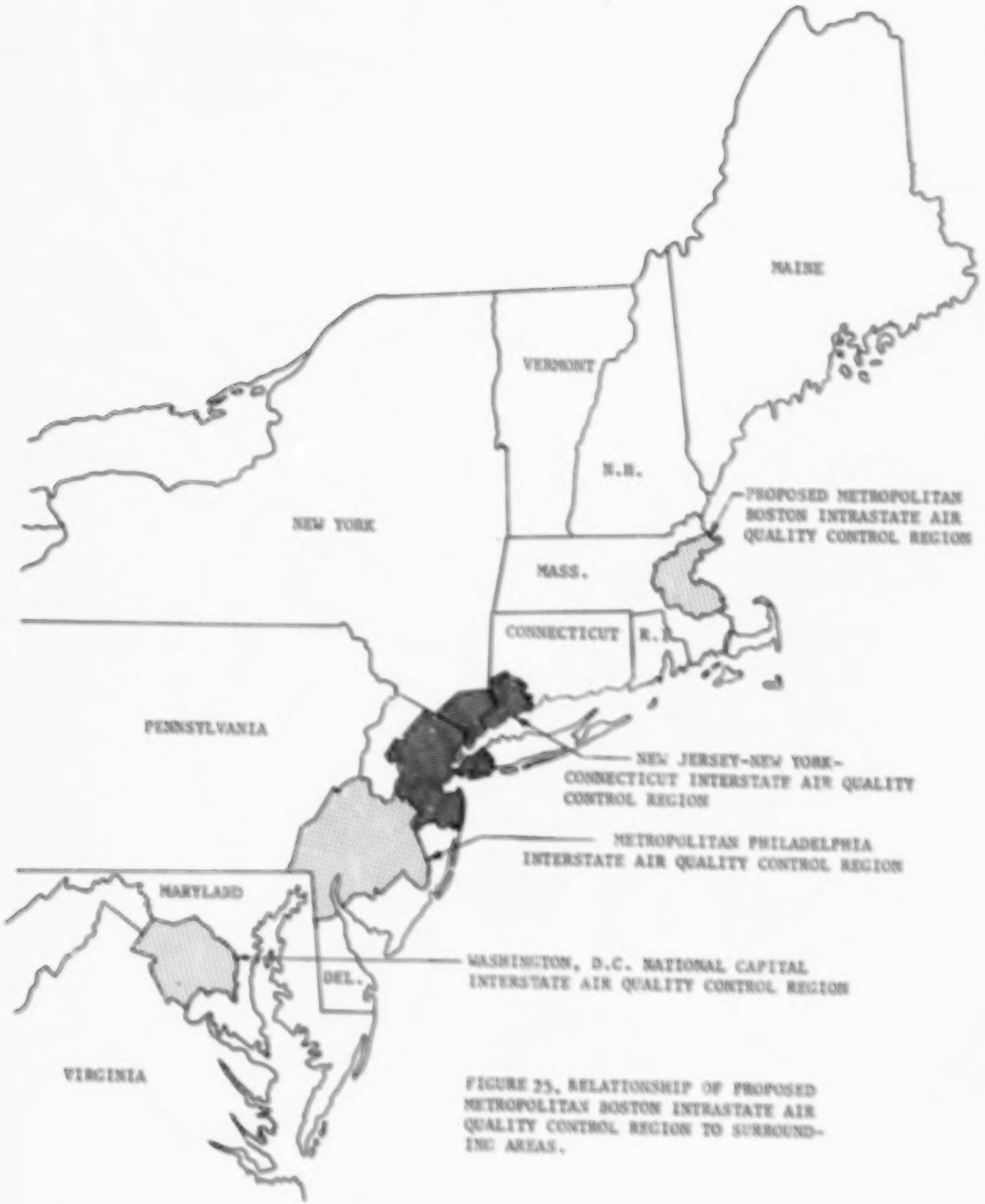

FIGURE 25. RELATIONSHIP OF PROPOSED METROPOLITAN BOSTON INTRASTATE AIR QUALITY CONTROL REGION TO SURROUNDING AREAS.

DISCUSSION OF PROPOSAL

To implement a successful air resource management program, an air quality control region should meet three basic conditions. First, its boundaries should encompass most pollution sources as well as most people and property affected by these sources. Second, the boundaries should encompass those locations where projected urbanization will create significant air pollution problems in the foreseeable future. Third, the boundaries should be chosen to be compatible with and foster unified and cooperative governmental administration of the air resource throughout the region. The proposed boundary of the Metropolitan Boston Intrastate Air Quality Control Region was designed to satisfy these requirements.

The "Evaluation of Engineering Factors" was directed toward the first of these conditions, while the "Evaluation of Urban Factors" considers the other two conditions. The Region as proposed consists of 20 cities and 78 towns. It creates an inclusive yet cohesive combination of jurisdictions for the administering of a region-wide air resource management program. The Region provides not only for the present needs of metropolitan Boston in order that acceptable air quality may be obtained, but also has been based upon future needs.

An examination of pollutant emission levels clearly shows that the preponderance of emissions (expressed in terms of density) occur in Boston or its neighboring cities and towns. The density

of emissions diminishes rapidly as one travels outward from the City of Boston. A region smaller in extent than that proposed would suffice to encompass the bulk of the pollutant sources. However, the majority of the people and property affected by the pollution emitted by these sources must be included in the Region in order that the first condition may be satisfied.

For this reason, the engineering evaluation utilizes a meteorological pollutant diffusion model to predict the extent of the pollutant problem. Equal-concentration contour maps depict the pollutant dispersion characteristics. The extent, shape, and relative spatial distribution of the contours makes it possible to select the Region that best satisfies the first condition. The location of the contour where a noticeable decrease in the concentration gradient occurs provides a good indication of the size of the Region. Based on relative predicted concentrations of sulfur dioxide, carbon monoxide, and suspended particulates, the Region extends northward to Hamilton and Topsfield, westward to Framingham, and southward to the city of Brockton. Diffusion model results adjusted to conform to measured concentrations, suggest that the Region should be geographically similar to that chosen through the use of relative concentrations.

The second condition states that the Region should include those areas where anticipated urbanization will create significant air pollution problems in the foreseeable future. This condition provides for the inclusion in the Region, areas that are at present non-urban

in character, or that are solely receptors of pollution transported from the urban areas. This provides for a "buffer zone" against pollution sources at the perimeters of the Region, based on present day development. Inclusion of these areas will at the same time allow for future growth. This arrangement provides a logical approach to an air resource management program by sensing where control efforts, a prerequisite for air of acceptable quality, will be needed.

An investigation was made to define the outer limits of an initial study area. The cities and towns within this area would be those closely integrated in metropolitan Boston, physically, socially, and economically. This study area was determined to be the combined area of the Metropolitan Area Planning Council and the Old Colony Planning Council. The municipalities within the jurisdiction of these two planning agencies have been included in overall planning with metropolitan Boston in the past. Peripheral jurisdictions within the area are not strongly tied to Boston as are others, and will not experience growth rates commensurate with the metropolis as a whole. A closer look at the pattern of urbanization was taken to determine whether the proposed Region should be lesser in extent than the above designated area.

Population projections indicate that growth will occur centered around Framingham, Brockton, and Peabody. These sub-regions serve as geographic hubs for extensive regional population growth and a concomitant increase in residential development. The core city,

Boston, and its immediate neighbors are at the same time projected to undergo a stabilization, and in some cases a decline, in growth. An extensive network of radial and circumferential highways will promote growth in the fringe cities and towns while regional integration through expanded and faster travel will be greatly induced.

The Region boundaries can be determined in part by combining the growth factor, applicable to individual cities and towns, with the concept of retaining a cohesive, yet inclusive area. Weighing these requirements against one another, it was concluded that the Region should extend to the outer bounds of the Metropolitan Area Planning Council (MAPC) to the north and to the outer bounds of the MAPC and Old Colony Planning Council to the south. The Region would include Ipswich, Middleton and Wilmington to the north, and Duxbury, Bridgewater and Foxborough to the south.

The proposed western boundary of the Region has been established by consideration of geographic growth trends. The towns of Acton, Maynard, Hudson and Marlborough are projected to undergo great population growth. For this reason they have been suggested for inclusion in the Region. Southborough has been proposed for inclusion because of its proximity to Framingham, the center of a highly urbanized sub-region of Boston. The likelihood of future urbanization spilling into Southborough from its neighboring towns cannot be discounted. The peripheral towns of Stow, Bolton, Holliston, Medway

and Milford are felt to be marginal in-so-far as inclusion in the proposed Region is concerned. For that reason, they have not been suggested for inclusion in the proposed Region at this time. Franklin and Bellingham have not been included in the proposal since they appear to be more closely related geographically and otherwise to Providence, Rhode Island. However, the final designation of the Region remains open as to the inclusion of these and other peripheral cities and towns subject to the comments and suggestions presented at the consultation by appropriate State and local authorities.

As is true of most efforts to draw boundaries around an area to differentiate it from its surroundings, there is always a likelihood of boundary conditions exisiting or developing. In the case of Air Quality Control Regions, such a boundary condition would exist where sources of pollution on one side of the region boundary affect in some real way air quality on the other side of the boundary. Relocating the boundary would only rarely provide relief from this condition. The solution is to be found in the way in which control efforts are implemented following the designation of an Air Quality Control Region. Consonant with the basic objective of providing desirable air quality within the problem area being designated as an Air Quality Control Region, the implementation plan that follows the designation should have provisions for the control of sources located close to but beyond the region boundaries. The level of control for such sources would be a function of, among other factors, the degree to which

emissions from sources cause air quality levels to exceed the standards chosen for application with the Air Quality Control Region.

The seriousness of these boundary conditions are likely to be diminished due to the likelihood of contiguous or nearly contiguous air quality control regions to the north, west, and south of Metropolitan Boston. Plans have already been announced by the Secretary, Department of Health, Education, and Welfare, for the designation of an air quality control region for Providence. It is likely that air quality control regions will eventually be designated for the Worcester and Lawrence-Lowell areas. The probability of these other regions occuring proximate to the Boston Region acted as constraints upon the extent of the initial study area and the final Region, as proposed. The Engineering Evaluation does, however, indicate that from a technical point of view the proposed Region is inclusive. From a consideration of urban factors the selection of boundaries was not always as clear; nevertheless, it is felt that the second and third conditions stated above are fulfilled in the Region boundaries, as proposed. As stated previously, however, the Region boundaries remain subject to revision suggested by consultation with State and local officials.

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